Berrara Creek Water Quality and Estuary Health Study

Shoalhaven City Council

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311015-00158

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Worley Group

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This report includes contributions in the form of monitoring data collected by Shoalhaven City Council, assessments undertaken by the Department of Planning and Environment (DP&E) and mapping undertaken by NSW Department of Primary Industries (DPI).

PROJECT 311015-00158 -ENV-REP – 002: Berrara Creek Water Quality and Estuary Health Study

Rev	Description	Author	Review	Advisian approval	Revision date	Client approval	Approval date
A	Draft for internal review	M. Priestley	K. Newton		21 Feb 2022		
B	Draft for internal review	M. Priestley	K. Newton		11 March 2022		
C	Draft issued to client	M. Priestley		C. Adamantidis	14 March 2022		14 March 2022
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0	Final	M. Priestley		C. Adamantidis	June 2023		

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Executive summary

Advisian has been engaged by Shoalhaven City Council (Council) to undertake a Coastal Management Program (CMP) for the Berrara Creek estuary. This CMP is intended to build upon the body of work that has already been completed in regard to coastal management for this estuary.

The purpose of this Water Quality and Estuary Health Study is to provide an up-to-date assessment of estuarine water quality and health to inform the scope and nature of coastal management actions during the future stages of Council's CMP development and implementation.

Limited sampling by the NSW Department of Planning and Environment (DP&E) over the summers of 2014-15 and 2020-21 found Berrara Creek to have good to excellent water quality based on their standard measurements of water clarity (turbidity) and algal abundance (chlorophyll-*a*) (DPIE, 2016). However, this current review of Councils historical trends in water quality within Berrara Creek is limited by data availability. Council's available data shows that turbidity is often outside of guidelines, especially during summer and spring. Limited nutrient, DO and chlorophyll-*a* data shows that most samples are within the guidelines.

Recreational water quality within Berrara Creek continues to be highly ranked as "Good" (4 star out of 4) for swimming and other water-based activities based on the NHRMC (2008) *Guidelines for Managing Risks in Recreational Waters* at the mouth of the estuary and upstream (near Fishermans Rock Road Crossing). The drainage line between Waterhaven Avenue and Meadowlake Avenue continues to be a source of faecal contamination, especially following heavy rainfall. However, recent enterococci monitoring results have improved in comparison to longer term monitoring (i.e. from 2013 and 2014). The enterococci results from monitoring sites located in the upper and lower reaches of the creek suggest that dilution and flushing within the creek is sufficient to maintain good microbial water quality elsewhere. The general advice from the National Health and Medical Research Council (NHMRC) (2008) applies - that swimming should be avoided for at least 3 days following rainfall in rivers, lakes and estuarine systems.

Estuarine macrophyte habitat mapping undertaken by NSW Department of Primary Industries (DPI) shows the mouth of Berrara Creek is lined with Zostera and Halophila seagrass andsmall patches of saltmarsh.

The findings of this Water Quality and Estuary Health Study are consistent with previous reports by Council and other relevant agencies (including NSW DP&E). The main issues identified in this study for Berrara Creek include limited water quality data availability, impacts on water quality associated with catchment inputs (mainly faecal contamination sources), threats to ecosystem health (invasive weeds, protection of significant habitat, threats to fish stocks, littering and dumping along foreshore and clearing of foreshore vegetation), foreshore erosion, climate change and sea level rises.

Recommendations have been made for an ongoing water quality monitoring program which outlines the recommended number of sampling sites, frequency of sampling, parameters, sampling methodology, limitations of reporting (LORs) and applicable trigger values. This recommendation will ensure that the ongoing water quality monitoring program can track improvements towards meeting current water quality objectives.

Acronyms and abbreviations

Acronym/abbreviation	Definition
AFRI	Acute Febrile Respiratory Illness
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZG	Australian and New Zealand Guidelines
CMP	Coastal Management Program
CZMP	Coastal Zone Management Plan
DEC	Department of Environment and Conservation
DECCW	Department of Environment, Climate Change and Water
DO	Dissolved Oxygen
DPI	Department of Primary Industries
DPE	Department of Planning and Environment
EAC	East Australian Current
FM Act	Fisheries Management Act 1994
GI	Gastrointestinal
GIS	Geographic Information System
ICOLL	Intermittently closed and open lagoons and lakes
IMCRA	Integrated Marine and Coastal Regionalisation of Australia
KEFs	Key Ecological Marine Features
LEP	Local Environmental Plan
LGA	Local Government Area
NOAEL	No Observed Adverse Effect Level
NSW	New South Wales
NSW EPA	New South Wales Environment Protection Authority
NRMS	National Resource Management Strategy
OEH	Office of Environment and Heritage
SEPP	State Environment Planning Policy
TN	Total Nitrate
TP	Total Phosphorus
TSS	Total Suspended Solids

1 Introduction

The purpose of this Water Quality and Estuary Health Study is to provide an up-to-date assessment of estuarine water quality and health within Berrara Creek to inform the scope and nature of coastal management actions to be included in the future stages of the Shoalhaven City Council (Council) Coastal Management Plan (CMP) development and implementation.

This report presents the following:

- A review of long-term routine estuary water quality monitoring data
- Summary statistics for key water quality parameters across the estuary
- A summary of NSW DP&E's Estuary Health Assessment for the estuary
- A summary of available estuarine macrophyte mapping
- A summary and overall assessment of recreational water quality
- A recommended sampling program for water quality and ecological health.

A desktop review of water quality data was undertaken for Berrara Creek, based on established protocols set out in the:

- NSW Natural Resources Monitoring, Evaluation and Reporting Program (NSW MER program) (DPIE 2016).
- Australian and New Zealand Water Quality Guidelines framework for "Developing a Water Quality Plan" (ANZG 2018),
- National Health and Medical Research Council "Guidelines for Managing Risks in Recreational Waters" (NHMRC 2008).
- Other relevant guidelines as applicable to meet previously identified water quality objectives.

1.1 General Information

Berrara Creek is located 2 kilometres (km) south of Swan Lake on the New South Wales (NSW) south coast (Figure 1-1). It has an estuary volume of 131.7 ML, estuary area of 0.3 km^2, average depth of 0.5 m and a catchment area of 35 km^2 (DP&E 2022a). It is an Intermittently Closed and Open Lake and Lagoon (ICOLL) with a predominantly open entrance, with the entrance having been observed to be closed occasionally (**Appendix A**). A conceptual model of an ICOLL, including key zones, is provided in Figure 1-2. The lower 3 km of Berrara Creek normally behaves as a tidal estuary, however, the mouth of the estuary does occasionally close to the sea (see the almost closed entrance area in December 2021 in Figure 1-3 and images in Figure 1-4). Information on known openings is only available prior to 2001 with additional information known about an artificial opening by the public mid-February 2020 following the bushfires and the associated first flush flood event that followed. The details of these openings are provided in **Appendix A**. The behaviour of the entrance affects the estuaries characteristics such as its estuarine ecosystem, water quality, flooding patterns and aesthetics. Despite its name, Berrara Creek is officially classified as a lagoon for the purposes of water quality and estuary health assessments against guideline trigger values (DPIE 2016).

Berrara Creek is largely surrounded by Conjola National Park. The waterway and its foreshore areas offer a range of recreational activities including passive recreation, fishing, boating, kayaking, cycling, swimming, walking and birdwatching. The endangered pied oystercatcher (*Haematopus longirostris*) (listed under the *NSW Biodiversity Conservation Act* 2016 (BC Act)) is known to nest in the entrance area between August and March (Figure 1-3). This region also has important cultural and spiritual significance to the local Aboriginal people (NSW NPWS 2012).

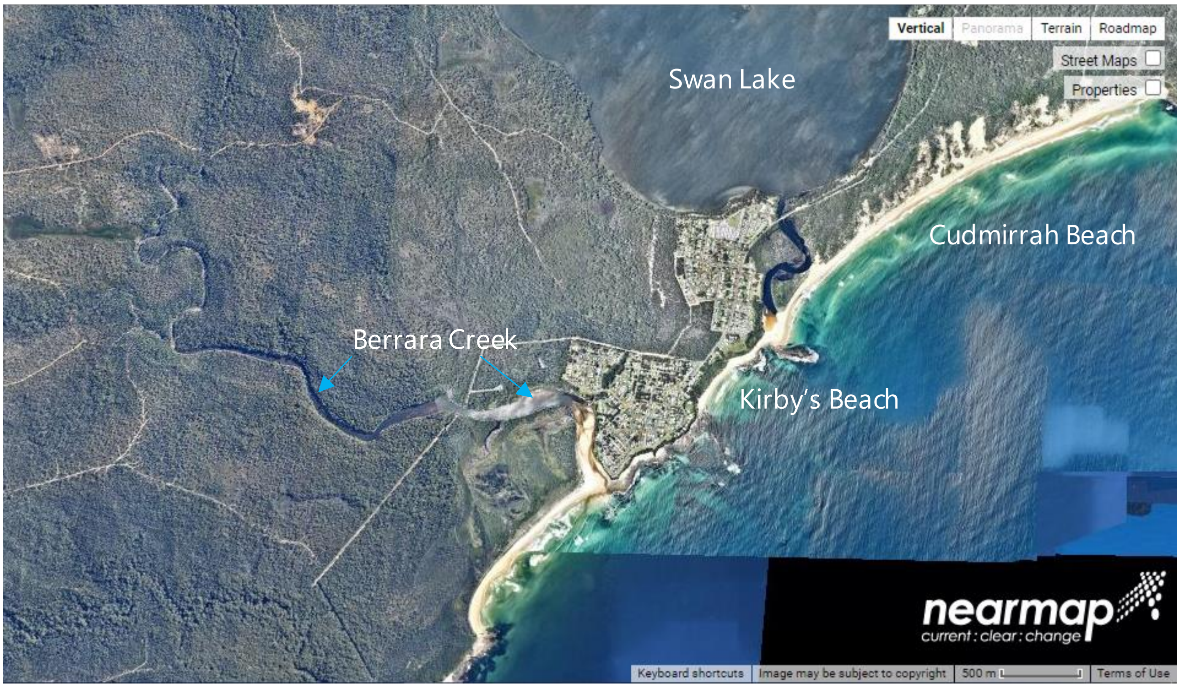

Figure 1-1 Location of Berrara Creek (top) and entrance area to Berrara Creek (bottom) in December 2021 (Nearmap 2022).

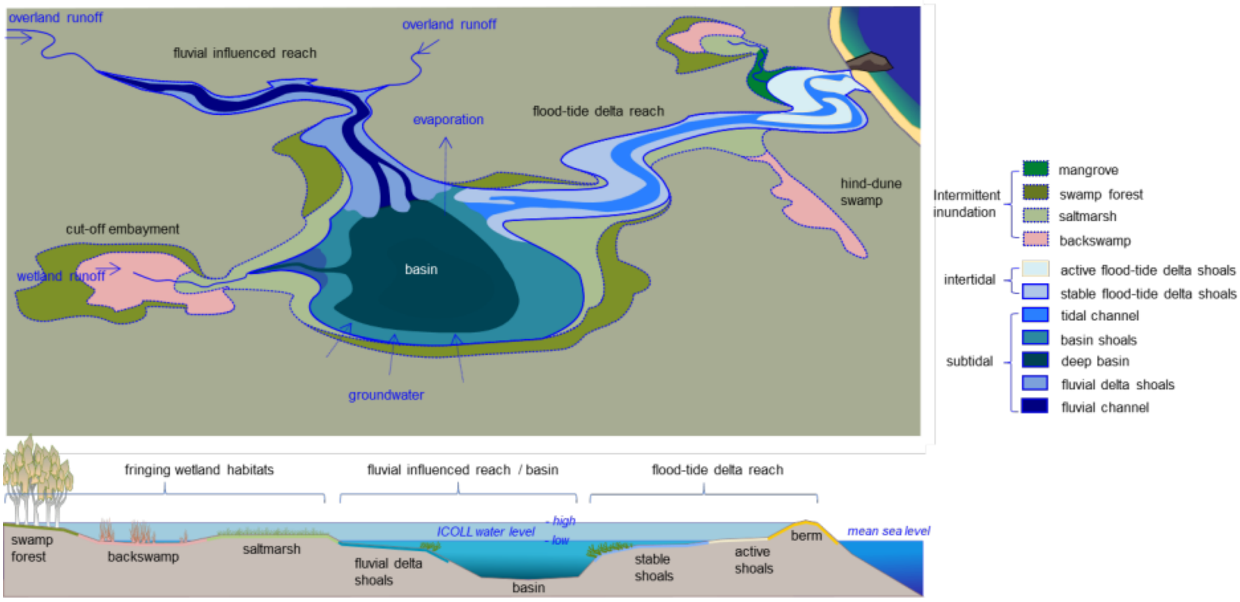

Figure 1-2 Conceptual model of ICOLLs including key zones (DPIE 2021).

Figure 1-3 Images of the Berrara Creek entrance area (showing the endangered pied oystercatcher nesting area) in November 2021 (Advisian).

Figure 1-4 Images of greater Berrara Creek in November 2021 (Advisian).

1.2 Waterway and Fish Habitat Classification

Under the *Fisheries NSW Policy and Guidelines for Fish Habitat Conservation and Management* (NSW DPI 2013) (Table 2 of the Policy), the waterways of Sussex Inlet and St. Georges Basin would be considered as a *CLASS 1 – Major Key Fish Habitat*, i.e. *"a marine or estuarine waterway or permanently flowing or flooded freshwater waterway (e.g. river or major creek), habitat of a threatened or protected species or 'critical habitat'"*.

Considering the specific attributes of the habitats present within Sussex Inlet and St Georges Basin, and in accordance with Table 1 of the Policy, the habitat would be considered as *TYPE 1 - Highly Sensitive Key Fish Habitat* as it contains:

- *Posidonia australis* (strapweed).
- Zostera, Heterozostera, Halophila and Ruppia species of seagrass beds >5 m^2 in area.
- Coastal saltmarsh >5 m^2 in area.

1.3 Water Quality Objectives

In 1999, the NSW Government introduced Water Quality Objectives as long-term goals for marine waters, estuaries and rivers to identify and protect identified values and uses on waterways through more sustainable and targeted management. The process for setting Water Quality Objectives was previously developed by the Department of Environment and Conservation (DEC 2005) based on the framework outlined in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000, now updated to ANZG 2018).

Water Quality Objectives for the estuaries on the NSW South Coast (DEC 2005) include:

- Protection of aquatic ecosystem health.
- Protection of primary and secondary contact recreational activities.
- Protection of visual amenity.
- Protection of aquatic food and commercial shellfish production.
- Water Quality Objectives for rivers on the NSW South Coast (DEC 2005) include:
- Maintain wetland and floodplain inundation.
- Manage groundwater for ecosystems.
- Minimise effects of weirs and other structures.
- Maintain or rehabilitate estuarine processes and habitats.

These Water Quality Objectives are currently under review by DP&E to ensure they reflect the current community values and uses of the waterways (DP&E 2022b).

1.4 Water Quality Issues – Berrara Creek

Swan Lake and Berrara Creek Natural Resources Management Strategy (NRMS) (Shoalhaven City Council 2002) has previously guided the management of the lagoon within six areas including water quality, erosion and sedimentation, entrance management, recreation and visual quality. Strategies that were included for water quality included:

- WQ1 - Minimise sewage contamination of Swan Lake and Berrara Creek from existing sewage management systems.
- WQ2 - Improve system for reuse and disposal of effluent from reticulated sewerage scheme.
- WQ3 - Control other pollutants at source.
- WQ4 - Minimise pollutant transport in stormwater drains.
- WQ5 - Ensure boating is not contaminating lake water.
- WQ6 – Monitor water quality.
- WQ7 - Educate residents and visitors on stormwater issues and solutions.

The key potential issues that are relevant to water quality within Berrara Creek that have been identified in previous studies (Advisian 2020, Shoalhaven City Council 2002) and community consultation (Advisian 2022b) include:

- Limited water quality monitoring data.

- Impacts on water quality associated with catchment inputs. Poor water quality in particular associated with sewage overflow events, and/or natural events. This in turn affects ecological health and recreational quality. Historical monitoring has indicated that there are faecal contamination sources within the drainage line between Waterhaven Avenue and Meadowlake Avenue (e.g. 14000 Enterococci units were measured at site E-337 on 29/1/2013).
- Impacts on water quality specifically following bushfires and subsequent flooding, including the 2019/20 bushfires. Following this event and flooding during February 2020, there were concerns from the community that bushfire debris had build up near the entrance and that raw sewage was being discharged into Berrara Creek. This led to the community to take it upon themselves to artificially open up the entrance to let debris and polluted water wash out. Subsequent to the 2019-20 bushfires, Sewage Pumping Station SPS 16 at Berrara was upgraded to include emergency storage overflow tanks in case of power outages, and Shoalhaven Water have reviewed and upgraded their communications and remote viewing system and pumps.
- Specific concerns raised during community workshops regarding potential releases of chlorinated water from the chlorine plant at Berrara Creek.
- Threats to ecosystem health and general loss of biodiversity and habitat:
  - Protection of important habitat of the endangered pied oystercatcher nesting sites.
  - Introduced animals from urban environment, such as foxes, cats, rats and rabbits.
  - Spread of weeds along foreshores.
  - A perceived threats to fish stocks from commercial and recreational fishing by the community.
- Littering and dumping of waste in the bush and foreshore.
- Clearing of foreshore vegetation.
- Foreshore erosion including the access stairs at Cudmirrah and Berrara Creek where people are taking alternative routes through vegetation.
- Management of the entrance of Berrara Creek, with artificial openings having occurredbased on perception of poor water quality within the lagoon.
- Climate change which is expected to increase the frequency of extreme events (such as bushfires, droughts and sea level rising causing inundation/flooding), which in turn influences water quality and ecological health.

1.5 Previous Water Quality Assessments

Since 1992, Council has collected water quality data within Berrara Creek. The frequency of sampling has been once per year for physicochemical parameters and chlorophyll-*a* and two to three times per year for enterococci at four sites. Nutrients (TN and TP) have been monitored twice per year at one site. See **Appendix B** for a summary of sampling frequency.

The aim of the monitoring program is to monitor water quality (via comparison to water quality guidelines relevant at the time) and ensure that waters are suitable for both primary and secondary recreational activities as defined by the National Health and Medical Research Council (NHMRC) (2008) and below:

- Primary recreational activities – swimming, kayaking and canoeing.
- Secondary recreational activities – boating, fishing and wading.

Recreational activities can be classified by the degree of water contact whereby with primary contact activities there is a higher possibility of water being swallowed or inhaled, or coming into contact with the ears, nose or cuts in the skin (NHMRC 2008).

A variety of pressure and stressors indicators are included in Council's routine monitoring program including:

- Physicochemistry – pH, water temperature (°C), salinity (ppt) and turbidity (NTU).
- Dissolved oxygen (DO) (mg/L and % saturation).
- Phytoplankton indicator – chlorophyll-*a* (µg/L).
- Microbial indicators - faecal coliforms (cfu/100mL) and enterococci (cfu/100mL).
- Nutrients - total nitrogen (TN) (µg/L) and total phosphorous (TP) (µg/L).

A review of historical water quality monitoring data was undertaken as part of the Swan Lake and Berrara Creek Management Plan (Shoalhaven City Council 2002). This report identified that historical water quality within Berrara Creek was generally good and has generally met the default guideline values for physical and chemical stressors for south-east Australia for slightly disturbed estuarine ecosystems in the ANZECC Guidelines for Fresh and Marine Water Quality (2000) (revised in 2018).

2 Water Quality Guidelines

2.1 Overview

The following guidelines are applicable to this site for water quality assessments:

- NSW Department of Environment and Conservation – Marine Water Quality Objectives for NSW Ocean Waters (DEC 2005).
- Assessing Estuary Ecosystem Health: Sampling, Data Analysis and Reporting Protocols. NSW Office of Environment and Heritage, Sydney. P.11 (OEH 2016).
- NSW DPIE Natural Resource Monitoring, Evaluation and Reporting (MER) Program Guideline Values (DPIE in preparation).
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) – Toxicant Default Guideline Values for 95% species protection. http://www.waterquality.gov.au/anz-guidelines.
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) – IMCRA mesoscale bioregions Default Guideline Values for Physical and Chemical Stressors, Batemans Shelf. http://www.waterquality.gov.au/anz-guidelines.
- National Health and Medical Research Council Water Quality Guidelines for Recreational Users (NHMRC 2008).

2.2 ANZG (2018) Framework

The Australian and New Zealand Water Quality Guidelines (ANZG 2018, previously ANZECC 2000) provide high-level guidance on the management context, ecological descriptions, biological indicator selection and other advice for five of Australia's six marine planning regions. The Great Barrier Reef Marine Park Authority (GBRMPA) provides separate advice for the Great Barrier Reef Marine Park (which represents the inshore portion of the Coral Sea Marine Region).

The ANZECC (2000) guidelines were revised in 2018 into the ANZG (2018) with key changes to ANZECC (2000): Improvements since 2000 (waterquality.gov.au). Some key changes include:

- Transition to an online based platform for Guidelines to facilitate more regular updates.
- Revision of the Water Quality Management Framework into a ten-step circular framework with improved guidance including applying to seven common applications including the implementation of a broadscale monitoring program.
- Revision of Default Guideline Values (DGVs) for protection of aquatic systems against toxicants, including revision of the methodology to derive new DGVs, review and update of some existing DGVs (previously listed under ANZECC 2000) and the addition of DGVs for new toxicants.
- In marine waters, physical and chemical stressor DGVs have been derived on a finer scale, using the Integrated Marine and Coastal Regionalisation of Australia (IMCRA 4.0) mesoscale bioregions and also divided into seasons. The study site is located within the Batemans Shelf

IMCRA bioregion. Some of these guidelines are in different units to those reported by laboratories so may require conversion or may not be applicable.

- In inland waters, physical and chemical stressor DGVs will be divided into finer scale, using drainage divisions. There will also be improved guidance around water quality management for temporary waters. Neither are available at the time of reporting, and therefore default to ANZECC (2000) guidelines for southeast Australia.
- Improved guidance and emphasis on the development and application of site-specific guidelines, which are to be used in preference to DGVs where established. Site-specific guidelines can be established if there is a sufficient monitoring data at appropriate reference locations or using a combination of methods.
- Removal of guidance on recreational waters and drinking water to avoid duplication with the Australian Drinking Water Guidelines (ADWG) (NHMRC 2011) and the Guidelines for Managing Risk in Recreational Waters (NHMRC 2008).

ANZG (2018) sets out a comprehensive systematic framework and guidance for water quality management, including specifically in relation to the assessment of wastewater discharges. The circular nature of the framework highlights the importance of continual improvement and adaptive management in water quality management. A schematic of the ANZG (2018) framework is shown in Figure 2-1 and a summary of the details required in each step of the process is provided below.

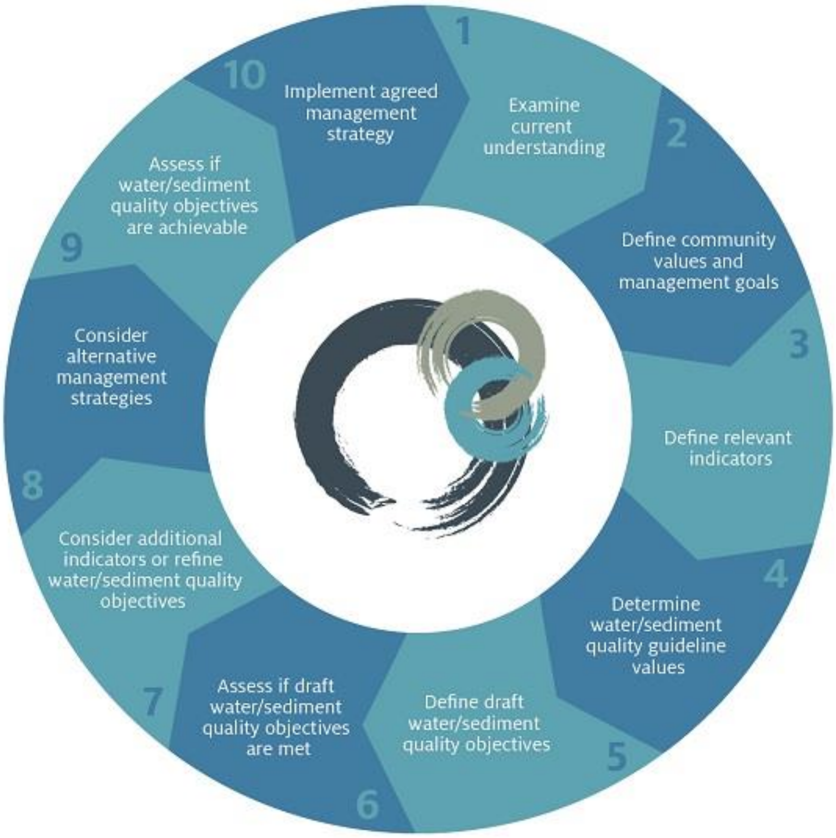

Figure 2-1 ANZG (2018) Water Quality Management Framework.

The ANZG (2018) framework emphasises the importance of a "multiple lines of evidence" approach and is shown in Figure 2-2.

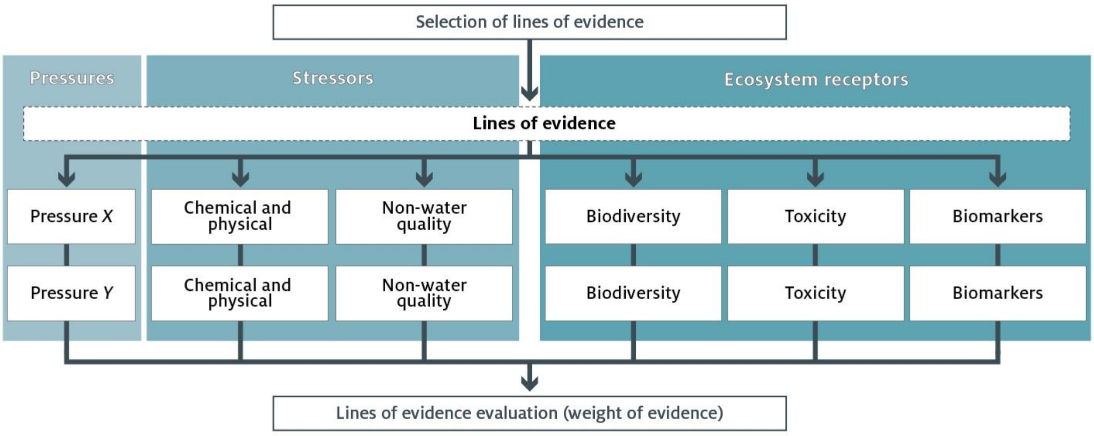

Figure 2-2 Weight of evidence approach across the pressure-stressor-ecosystem pathway (ANZG 2018).

2.3 Monitoring and Evaluation Reporting Program

The NSW Natural Resources Monitoring and Evaluation Program (MER Program) is coordinated by NSW DP&E (formerly OEH then DPIE) and is generally implemented through Coastal Management Programs (CMPs). This includes standardised protocols for undertaking assessments of estuary ecosystem health including sampling, data analysis and reporting, as outlined in OEH (2016).

Guideline values are used to comparatively assess whether water quality indicators are outside of the expected range and indicate potential for undesirable ecosystem health. As part of the MER program, DP&E has previously determined guideline values for NSW inland waterways including lagoons using the ANZECC (2000) and ANZG (2018) approach of calculation of the 80th percentile of all data at appropriate reference locations within NSW in various estuary types (DP&E in preparation). Reference estuaries are generally defined as having minimal impacts on chlorophyll-*a* and turbidity. DP&E updates guideline values periodically as additional data is available.

2.3.1 MER Triggers for Protection of Aquatic Ecosystems

The relevant water quality guidelines are based on NSW DP&E MER guideline values, ANZECC (2000) and ANZG (2018) default water quality guidelines, as they apply to protection of aquatic ecosystems (Lagoons). Adopted guidelines are shown in Table 2-1. The NSW DP&E MER guideline values were last revised in 2020 and provided by DP&E (in preparation).

Table 2-1 NSW DP&E MER values for inland waters.

Parameter	Lagoons
Total dissolved P (mg/L)	0.01
Total dissolved N (mg/L)	0.56
TP (mg/L)	0.025
TN (mg/L)	0.625

Parameter	Lagoons
Chlorophyll-*a*	3.9
Turbidity (NTU)	4.4
pH - upper	8.9
pH - lower	7.5
DO - upper %	107
DO - lower %	76

2.4 Recreational Water Quality

Microbial assessment (of enterococci) measures the impact of pollution sources, enables the effectiveness of stormwater and wastewater management practices to be assessed and highlights areas where further work is needed. Swimming sites are graded as Very Good, Good, Fair, Poor or Very Poor in accordance with the National Health and Medical Research Council (NHMRC) 2008 Guidelines for Managing Risks in Recreational Waters. Grades are determined from the most recent 100 water quality results (two to four years' worth of data) and a risk assessment of potential pollution sources. There are four Microbial Assessment Categories (A to D) and these are determined from the 95th percentile of an enterococci dataset of at least 100 data points. Each category is associated with a risk of illness determined from epidemiological studies (refer to Table 2-2). The risks of illness are the overall risk of illness associated with the 95th percentile of the enterococci dataset.

Table 2-2 Microbial assessment categories and risk of illness (from NHMRC 2008).

Category	95th percentile for enterococci per 100mL	Basis of derivation	Estimation of probability
A	≤40	This value is below the NOAEL (No Observed Adverse Effect Level, the level below which no adverse effects have been observed in most epidemiological studies).	Gastrointestinal (GI) illness risk: < 1% Acute febrile respiratory illness (AFRI) risk: < 0.3% The 95th%ile of 40/100mL relates to an average probability of less than one case of gastroenteritis in every 100 exposures. The AFRI would be negligible.
B	41-200	The 200 per 100mL value is above the threshold of illness transmission reported in most epidemiological studies.	GI illness risk: 1-5% AFRI risk: 0.3-1.9% The 95th%ile of 200/100mL relates to an average probability of one case of gastroenteritis in every 20 exposures. The AFRI would be ~ 1 in 50 exposures.

Category	95^{th} percentile for enterococci per 100mL	Basis of derivation	Estimation of probability
C	201-500	A substantial increase in probability of adverse health outcomes for which dose response data is available.	GI illness risk: 5-10% AFRI risk: 1.9-3.9% The 95^{th}%ile of 200/100mL relates to an average probability of one case of gastroenteritis in every 10-20 exposures. The AFRI would be ~ 1 in 50 to 1 in 25 exposures.
D	>501	Above this level there may be significant risk of high levels of illness transmission.	GI illness risk: >10% AFRI risk: >3.9% The 95^{th}%ile of 200/100mL relates to a greater than 10% change of illness per exposure. The AFRI would be ~ 1 in 25 exposures.

AFRI = acute febrile respiratory illness; GI = gastrointestinal, NHMRC = National, Health and Medical Research Council.

Other relevant NHMRC (2008) guidelines for primary contact recreation are shown in Table 2-3.

Table 2-3 NHMRC Guidelines for Primary Contact Recreation.

Water Quality Guideline	Parameter	Guideline Value	NSW Water Quality Objective
Primary Contact Recreational – biological (NHMRC 2008)	Faecal coliforms	Median over bathing season of less than 150 faecal coliforms/100 mL.	Median over bathing season of less than 150 faecal coliforms/100 mL with 4 out of 5 samples.
Primary Contact Recreational – physiochemical (NHMRC 2008)	Visual clarity	Natural visual clarity should not be reduced by more than 20%. Horizontal sighting of a 200 mm black disc should exceed 1.6 m.	A 200 mm diameter black disc should be able to be sighted horizontally from a distance of more than 1.6 m.
	pH	pH of the water should be within the range of 5.0-9.0 assuming that the buffering capacity of the water is low near the extremes of the pH limits.	--
	Temperature	15-35˚C (for prolonged exposure).	--
	Salinity (TDS)	<1,000,000 µg/L	--
	Surface films	Oil and petrochemicals should not be noticeable as a visible film on the water nor should they be detectable by odour.	--

-- not listed.

At a minimum for a microbial assessment as per the NHMRC Guidelines, microbial monitoring is undertaken as screening to assess suitability of waters for recreational water quality. If there are elevated results, then a detailed assessment would follow to combine microbial monitoring with a sanitary inspection that includes the following:

- Assessment of sewage outfalls and stormwater discharges - present or absent, type of treatment, effectiveness of outfall treatment and location of pumping stations and overflow points.
- Riverine sewage discharges – present or absent, type of treatment, population size and river flow.
- Bathers (i.e. number of bathers and periods of high use).
- Dilution.
- Any additional information that might affect indicators such as rainfall, wind, tides, currents, water releases and flushing rates.

The combination of microbial monitoring and sanitary inspection would then be used to categorise water quality as per Table 2-4.

A sanitary inspection was not possible, as this is site specific and undertaken at the same time as microbial sampling. Instead, a high-level review of faecal contamination sources within the catchment was undertaken, to provide a combined assessment with microbial monitoring data to provide an evaluation of suitability for identified recreational activities.

Table 2-4 NHMRC (2008) classification matrix for faecal pollution of recreational waters.

		Microbial water quality assessment category (95^{th} percentiles — intestinal enterococci/100 mL)				Exceptional circumstances[c]
		A ≤ 40	B 41–200	C 201–500	D > 500	
Sanitary inspection category (Susceptibility to faecal influence)	Very low	Very good	Very good	Follow up[b]	Follow up[b]	ACTION
	Low	Very good	Good	Follow up[b]	Follow up[b]	
	Moderate	Good[a]	Good	Poor	Poor	
	High	Good[a]	Fair[a]	Poor	Very poor	
	Very high	Follow up[a]	Fair[a]	Poor	Very poor	
	Exceptional circumstances[c]	ACTION				

a Indicates possible discontinuous/sporadic contamination (often driven by results such as rainfall). This is most commonly associated with the presence of sewage – contaminated stormwater. These results should be investigated further, and initial follow-up should include verification of the sanitary inspection category and ensuring that samples recorded include 'event' periods. Confirm analytical results, review possible analytical errors.

b Implies nonsewage sources of faecal indicators (eg livestock), which need to be verified.

c Exceptional circumstances are known periods of higher risk such as during an outbreak involving a human or other pathogen that may be waterborne (eg avian botulism — where outbreaks of avian botulism occur, swimming or other aquatic recreational activities should not be permitted), or the rupture of a sewer in a recreational water catchment area etc. Under such circumstances the classification matrix may not fairly represent risk/safety.

* In certain circumstances there may be a risk of transmission of pathogens associated with more severe health effects through recreational water use. The human health risk depends greatly on specific (often local) circumstances. Public health authorities should be engaged in the identification and interpretation of such conditions.

3 Routine Water Quality Monitoring

3.1 Methodology

Routine water quality monitoring is undertaken by Council in Berrara Creek to assess the environmental health of lagoon waters and impacts from faecal contamination sources. This monitoring data is published online on the Aquadata portal (https://www.esdat.net/Aquadata_Web_Based_Water_Quality_Public_Portal.aspx) and includes raw data and mapping for Shoalhaven (https://webreports.esdat.net/SCC#results-map).

A review of routine monitoring data from the past decade (2010 – 2021) was undertaken for Berrara Creek. This was based on selected monitoring sites (E-336, E-337, E-338 and E-711) (see Figure 3-1) and historical data from January 2010 to October 2021. The collated raw water quality dataset was provided by Council. An initial quality review of the data was undertaken to identify any anomalous values resulting from instrumentation errors, transcription errors or extreme outliers. Extreme outliers were classified as values which were more than four standard deviations from the median and were also outside the possible range that would be expected for that parameter (including due to pollution events).

This review included the removal of:

- pH values below 5.
- DO above 100%.
- Electrical conductivity values below 100 µS/cm.
- Obvious data entry errors.

No laboratory measured results were required to be removed from the dataset. The final collated and reviewed data and more detail on the data review process is provided in **Appendix B**.

For turbidity there may have been overestimation associated with some elevated values which may be due to:

- Calibration – turbidity meters need to be calibrated to low readings (0-20 NTU) or can result in overestimated readings.
- Instrumentation errors.
- Sampling - turbidity readings taken close to the estuary bed or in areas of current can result in elevated readings.

It is difficult to confirm this assumption in the absence of chlorophyll–*a* and TSS data.

Boxplot graphs were prepared in Minitab 16.0 (2010) for key water quality parameters presented by site and season in **Appendix C**.

3.2 Location of Monitoring Sites

The location of monitoring sites included in the review for Berrara Creek are shown in Figure 3-1. Images of sites E-336, E- 337 and E-338 (at the entrance to the lagoon from the ocean) are provided in Figure 3-2.

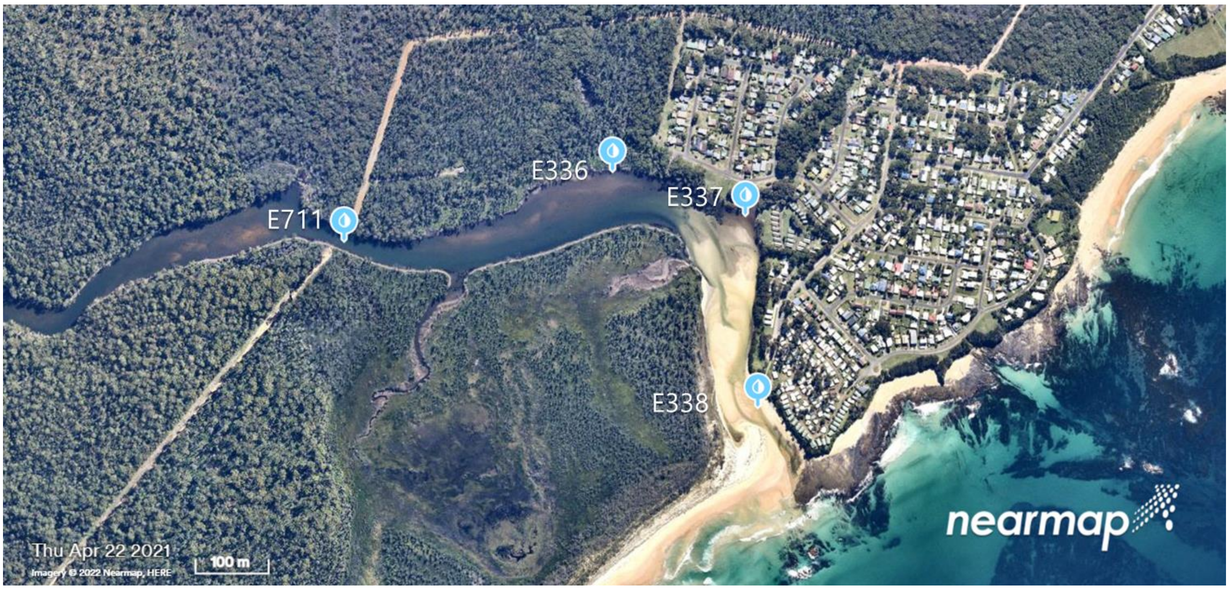

Figure 3-1 Location of all environmental water quality monitoring sites by Shoalhaven City Council within the project area.

Figure 3-2 Images of Berrara Creek water quality monitoring locations E-336 (top), E-337 (middle) and E-338 (bottom) in November 2021 (Advisian 2021).

3.3 Review of Long-Term Water Quality Data

A review of historical water quality data was undertaken for Berrara Creek. The focus of the review was to identify any broadscale water quality issues or hotspots.

Key water quality statistics (including average, standard deviation, median, minimum, maximum and count of sample replicates) are included in **Appendix B**.

Boxplots of the water quality data by area, site, season and with comparison to any available and applicable water quality guidelines are shown in **Appendix D**. As the sample replicates during winter were limited, the results are not discussed below. The key water quality results are as follows:

- **Temperature (°C)** – All monitoring sites in Berrara Creek had low variability during summer and more variable levels during autumn and spring (**Appendix D**). The site close to Lakeland Avenue (E-337) had the most variable temperatures during spring. With this exception, there was little variation between monitoring sites within respective seasons.
- **Dissolved Oxygen (DO) (%saturation)** – At the monitoring sites E-336 and E-337 (sites located close to the shoreline) the median concentrations of DO were below the DP&E MER guideline upper and lower limits for Lagoons (**Appendix D**). DO levels at E-338 (nearest the ocean entrance to the lagoon) and E-711 (upstream near Fishermans Rock Road Bridge) recorded median values within the DP&E MER guideline limits for Lagoons during summer, autumn, winter and spring.
- **pH** – Most median pH values were within or just below the DP&E MER guideline value range for lagoons (**Appendix D**). The exception was monitoring sites E-336 and E-337 (sites located close to the shoreline) during summer, which had median pH values well below the lower limit guideline value.
- **Salinity (ppt)** – Salinity levels were variable and reflected the influence of tidal flushing within Berrara Creek. There were little differences between monitoring sites, except during autumn where there were fluctuations between 6.5 and 20.6 parts per thousand (ppt) (**Appendix D**). The salinity has increased over time with higher salinity values measured in 2014 – 2020, compared to 2010 – 2013 (**Appendix D**). This suggests that there has been more opening/flushing in more recent years.

- **Turbidity (NTU)** - Monitoring sites within Berrara Creek showed high variability in turbidity with most values elevated above the respective DP&E MER guideline values for Lagoons during summer, autumn and spring (**Appendix D**). Turbidity was highest during summer. The turbidity results should be viewed with the caveat that the dataset may include overestimated results (either due to calibration, instrumentation errors or sampling methods as outlined in Section 3.1).
- **Chlorophyll-*a* (mg/m^3)** – Very limited monitoring has been undertaken for chlorophyll-*a* within Berrara Creek, with the most recent dataset at E-338 in summer showing a median value below the DP&E MER guideline value for Lagoons (**Appendix D**).
- **Total Nitrogen (mg/L)** – The limited monitoring that has been undertaken for TN at E-338 shows values that are mostly below the DP&E MER guideline value (**Appendix D**).
- **Total Phosphorous (mg/L)** – The limited monitoring that has been undertaken for TP at E-338 has shown some values above the DP&E MER guideline values (**Appendix D**).
- **Faecal coliforms and enterococci (CFU/100mL)** – Faecal indicators were generally low at all sites (**Appendix D**). However, there were occasional elevated outliers following high rainfall events in Summer during 2013 and 2014. There have been improvements in regard to levels of faecal contamination in the catchment since this time (refer to **Appendix D** and Section 6).

Overall, the review shows that based on available water quality monitoring undertaken within Berrara Creek, that water quality is generally 'good' quality, but this varies between sampling sites. Monitoring sites E-338 and E-711, which are located in the middle of the lagoon, have median values consistently within the DP&E MER Guidelines for lagoons. This aligns with the DP&E estuary health assessment which also showed good to excellent results for 2020 - 2021 (Section 5).

In contrast, water quality varies from 'moderate' to 'good' at monitoring sites E-336 and E-337, with occasional elevated values of turbidity, enterococci, low DO and pH outside of the guidelines and NHRMC (2008) (in relation the 95%ile of enterococci values, refer to Section 4). These monitoring sites are located closer to the shoreline, which can influence physicochemistry results and may not be as representative of estuary health.

3.4 Multivariate Analysis

Analysis of physicochemistry data (i.e. temperature, turbidity, DO, pH and salinity) and chlorophyll-*a* for St Georges Basin and Sussex Inlet and the methodology used is presented in **Appendix D**. This analysis was undertaken to understand the patterns in the dataset and interpret whether there are differences in water quality between sites, years or seasons. This information is useful to understand long term trends but also to inform future monitoring requirements (in terms of site replication and frequency of sampling required).

The water quality analysis shows:

- There are no apparent differences in physicochemistry between individual sites (**Appendix E**).
- There are apparent differences in the physiochemical water quality signature between sampling years (**Appendix E**). In 2010-2013, there was more variability and lower salinity in comparison to the data in 2014-2020. Median DO was lower in 2012 in comparison to all other sampling

years. Median turbidity levels were also elevated during 2013 in comparison to all other sampling years.

- There were little differences in physiochemistry between seasons, with the exception of lower water temperatures and turbidity during winter (although this season was only represented by four samples within 2014, so this is not considered a reliable pattern) (**Appendix E**).

4 Estuary Macrophyte Mapping (NSW DPI)

NSW DPI undertakes macrophyte mapping of most estuarine habitats within NSW using methods developed over decades (Creese et al. 2019; Sainty 2012; West et al. 1985; West and Glasby 2021). Mapping for Berrara Creek was last undertaken in 2005.

Estuarine macrophyte mapping is available via the Estuarine Habitat Dashboard (NSW DPI 2022) which includes the ability to view mapping and undertake a change analysis comparing the percentage mapped macrophyte area between mapping times.

It is noted that due to differences in mapping techniques, mapping from 1982 generally is an overestimation of the large areas of macrophytes.

4.1 1982 and 2005 Mapping

Estuarine macrophyte habitat mapping undertaken by NSW DPI in 1982 is presented in Figure 4-1 and for 2005 in Figure 4-2. Note that there has been a considerable change in mapping methodology since 1982, which is thought to have resulted in a decrease in estimates in 2005.

Habitat mapping is available via https://nsw-dpi.shinyapps.io/NSW_Estuarine_Habitat/.

The mapping shows that during 1982, the mouth of Berrara Creek had small patches of Zostera mostly to the north. No other macrophyte species were mapped during 1982.

In comparison, mapping during 2005 shows more extensive macrophyte growth with the mouth of Berrara Creek and approximately 0.5 km upstream is lined with the seagrass species Zostera and Halophila in the subtidal / intertidal areas, with small patches of saltmarsh located in the higher intertidal zone.

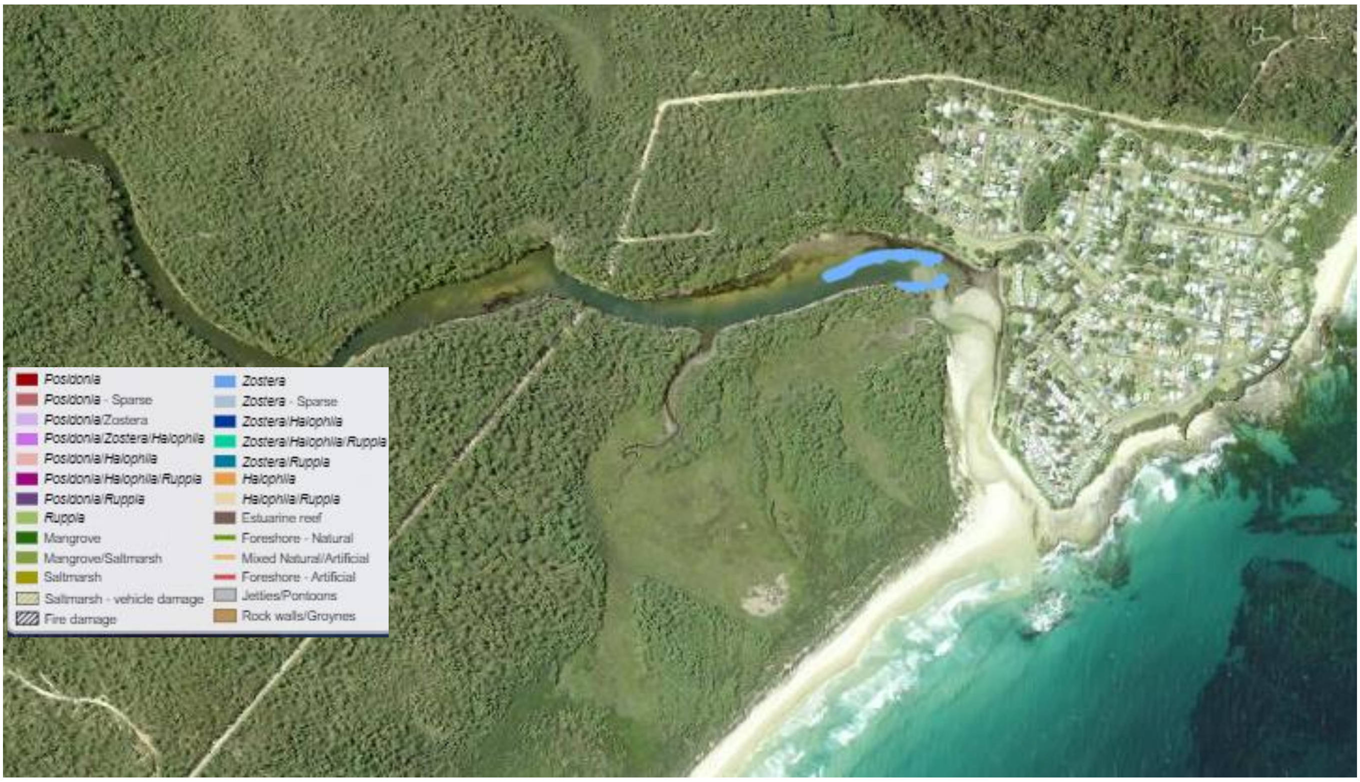

Figure 4-1 NSW DPI estuarine macrophyte mapping for Berrara Creek in 1982 (NSW DPI 2022).

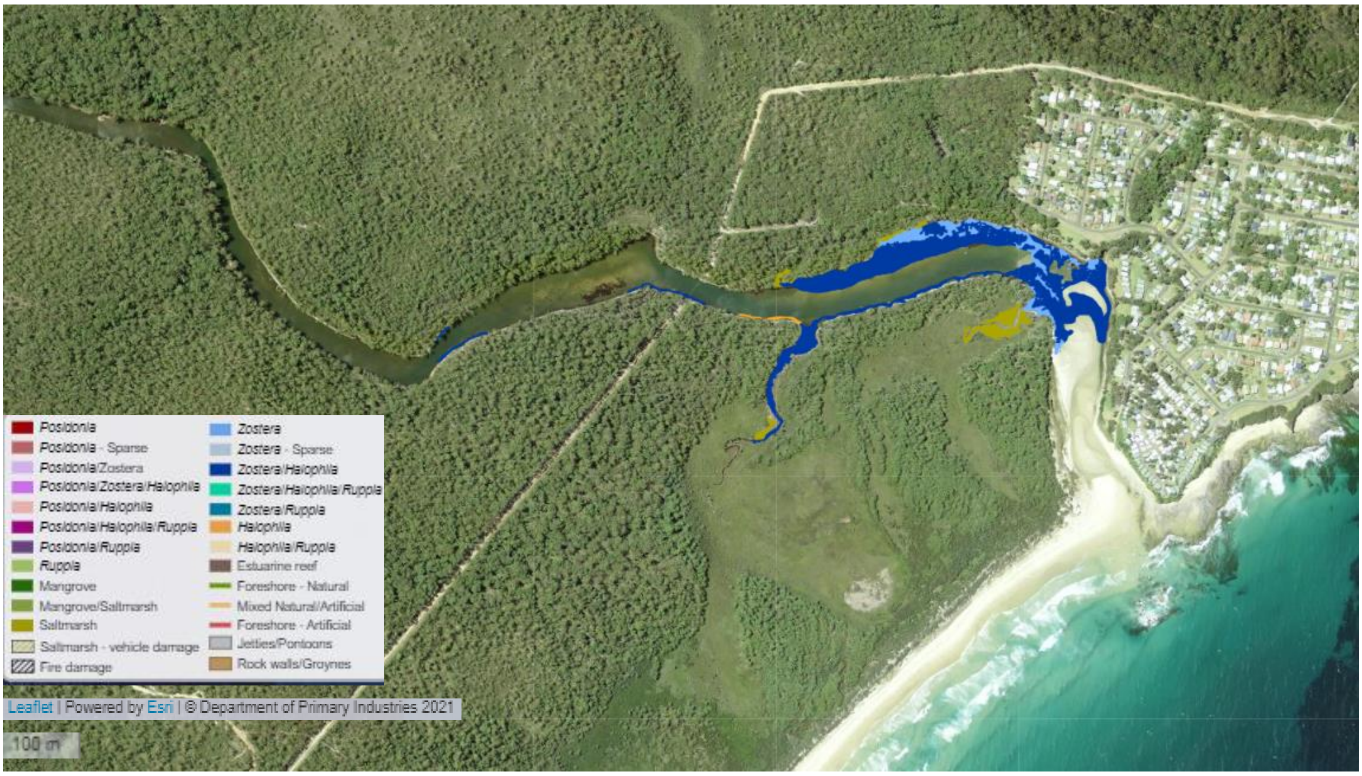

Figure 4-2 NSW DPI estuarine macrophyte mapping for Berrara Creek in 2005 (NSW DPI 2022).

4.2 1982 versus 2005

A comparison between the spatial distribution and area of macrophytes is available via the NSW DPI Estuarine Habitat Dashboard (NSW DPI 2022) (Figure 4-3). The mapping shows that there has been a significant increase in the area of Zostera in 2005 compared to 1982. In 1982, there was ~0.8 ha mapped while in 2005 this has increased to over 5 ha. In 2005, there was also over 4 ha of Halophila and over 0.5 ha of saltmarsh, which was not mapped in 1982.

As noted above, there was a difference in mapping techniques between these periods so the comparison between these sampling times is considered to be highly indicative. Mapping during 1982 may have missed small patches and not accounted for all macrophyte species.

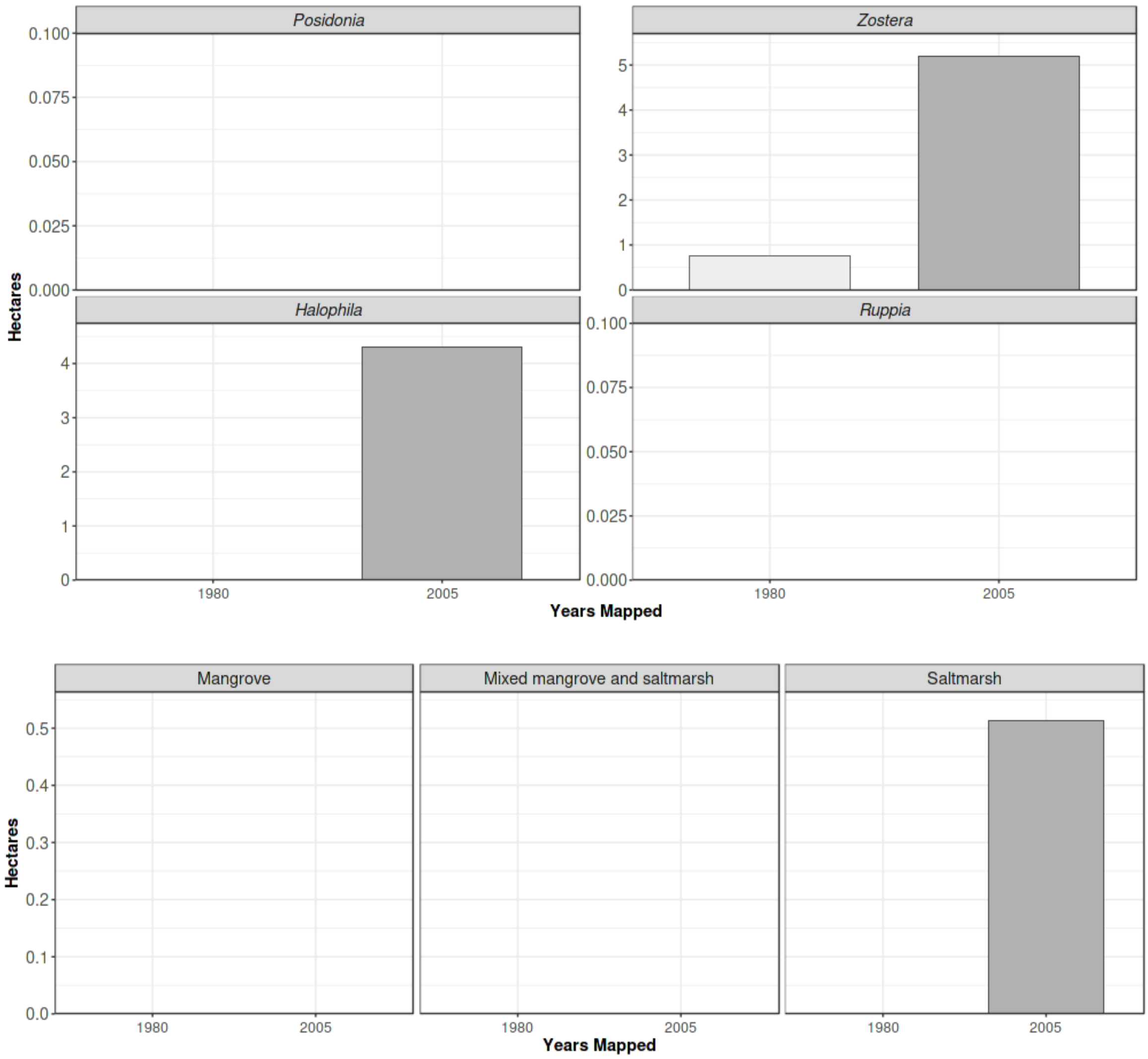

Figure 4-3 NSW DPI estuarine macrophyte mapping – data summary of changes in area (hectares) of macrophytes in Berrara Creek between 1982 in comparison to 2005 (NSW DPI 2021).

5 Estuary Health Assessment (DP&E)

5.1 Methodology

NSW DP&E Science team monitors ecosystem health in a subset of NSW estuaries approximately once every three years. The most recent assessment of estuary health for Berrara Creek was undertaken during 2020 – 2021. A previous assessment was also done in 2014-15. The results of these assessments are published on the DP&E web-site (i.e. Berrara Creek | NSW Environment, Energy and Science) . These were based on the protocols outlined in the NSW Monitoring, Evaluation and Reporting Strategy (MER) methodology for Assessing Estuary Ecosystem Health: Sampling Data Analysis and Reporting Protocols (OEH 2016).

The six steps outlined in the NSW MER program include:

1. Calculation of the Non-Compliance Score (NC1) which is the proportion of time that measured values of the indicators are outside the adopted trigger value.
2. Calculation of the Worst Expected Value (WEV) by calculation of the 95^{th}%ile or adoption of those proposed in the MER Program.
3. Calculation of the Distance Score (Dsi) from the trigger value whereby Dsi = (value – trigger value) / (WEV – trigger value).
4. Calculation of an Indicator Score (Isi) for each zone: Isi = √(Nci x Dsi).
5. Calculation of the Zone Score (ZS) whereby ZS = (Isc + Ist) / 2.
6. Grading the zone as A (Very Good/Excellent), B (Good), C (Fair), D (Poor) or E (Very Poor) (Figure 5-1),

Score Criteria	Rating
4.3 to 5.0	Very Good
3.5 to 4.2	Good
2.7 to 3.4	Fair
1.9 to 2.6	Poor
< 1.8	Very Poor

Figure 5-1 Scoring classes used to assign overall grades of estuary health (Roper et al. 2011).

The relevant temporal scale for the MER Program targets the maximum chlorophyll-*a* period from mid-November to the end of March. A minimum of six samples is recommended from within this period, with more samples providing more statistical confidence.

5.2 Assessment

The estuary health assessment for Berrara Creek for 2020 – 2021 was undertaken by DP&E and has been published online (DP&E 2022c). Water quality data was used to assess ecosystem health using the methodology outlined in the NSW Monitoring, Evaluation and Reporting Strategy (MER) Methodology for Assessing Estuary Ecosystem Health: Sampling, Data Analysis and Reporting Protocols (OEH 2016).

The assessment was undertaken for summer of 2020/2021 using routine monitoring data for water clarity (turbidity) and algae (chlorophyll - *a*). The overall estuary health grades were within the highest category "A" for excellent and despite the bushfires, water quality shows a slight improvement since 2014-15 (DP&E 2022c). Refer to Figure 5-2 and Figure 5-3.

Year	Overall Grade	Algae	Water Clarity
2020-2021	A	A	A
2019-20 Bushfires			
2014-2015	B	A	B

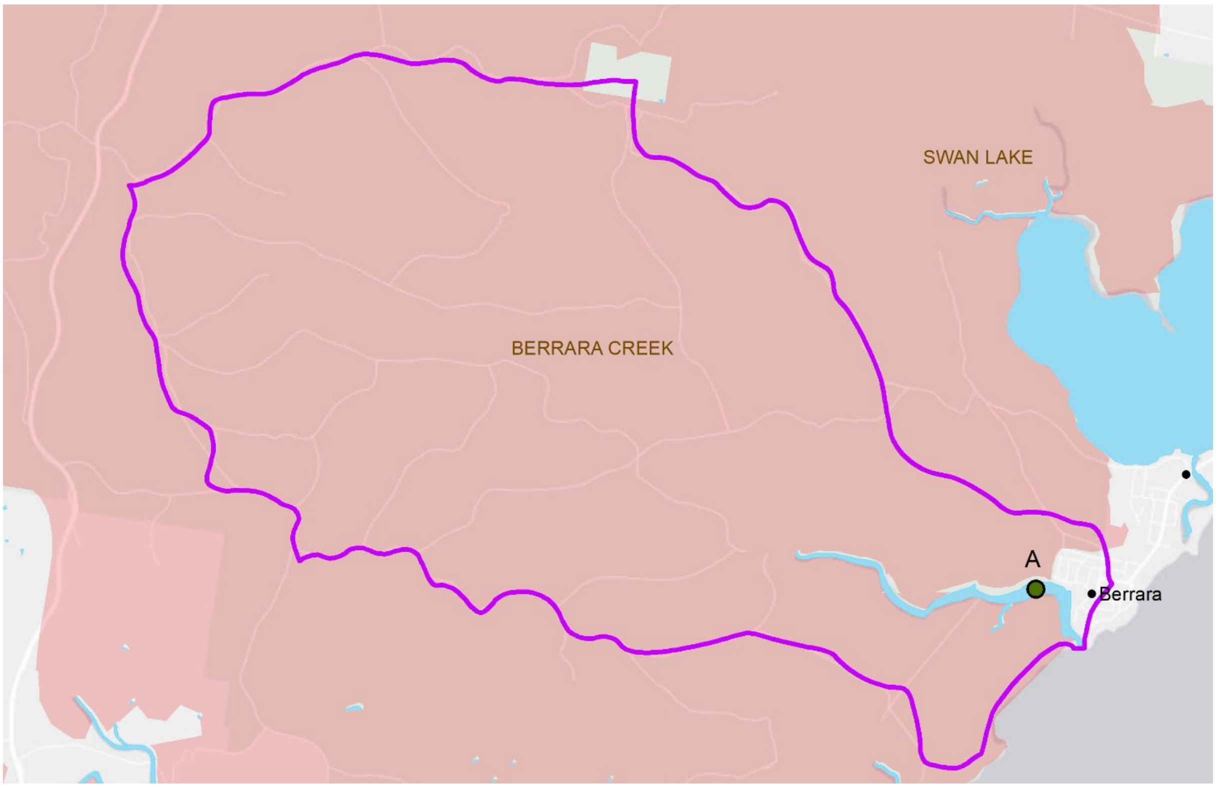

Figure 5-2 Berrara Creek Estuary Health Assessment Map (DP&E 2022c).

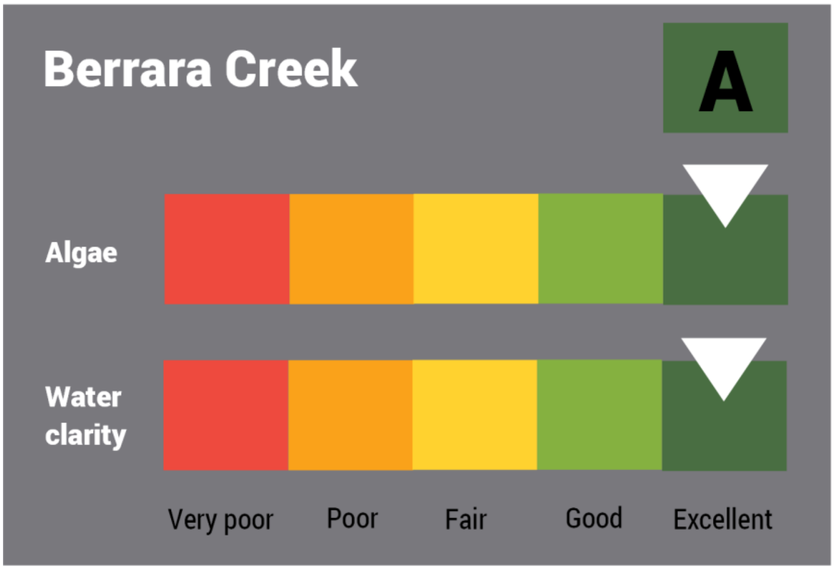

Figure 5-3 Berrara Creek Estuary Health Assessment (DP&E 2022c).

6 Recreational Water Quality

Recreational water quality is assessed using microbial monitoring, in particular, assessment of enterococci data.

A summary table of all water quality parameters measured between 2010 and 2021, including the percentage of samples that exceeded predefined trigger values for those parameters, is provided in Table 6-1.

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Table 6-1 Water Quality Summary Statistics, 2010 - 2021

Site	Stats	Temperature	Dissolved Oxygen (% Saturation)	Dissolved Oxygen	pH	Salinity	Electrical Conductivity	Turbidity	Faecal Coliforms	Enterococci	Chlorophyll a	Nitrogen	Total Phosphorus	Total Phosphorus as P (Organic Phosphate as P)	TDS
	EQL	0.1	0.1	0.1	0.1		100	0.1	1	1	0.5	0.025	0.005	0.005	1
	NSW DPIE MER Triggers - Lagoons		76-107		7.5-8.9			4.4			3.9	0.625	0.025	0.01	
	NHRMC (2008) Primary contact recreational	15-35							median <150	<40 for GI*<1%					
Site	**Stats**	**°C**	**%**	**mg/L**	**-**	**ppt**	**µS/cm**	**ntu**	**CFU/100mL**	**cfu/100mL**	**mg/m3**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
E-336	Mean	23.06	80.32	5.76	7.78	27.07	42310	19.81	127.83	459.76	6.37	--	--	--	24250
	StDeV	4.18	18.50	1.54	0.49	7.98	12105	27.00	518.25	2196.18	--	--	--	--	6652
	Median	24.52	80.80	5.64	7.86	29.31	48790	6.70	3.00	10.00	6.37	--	--	--	24500
	Min	12.55	46.70	3.00	6.19	14.64	16690	0.10	0.00	0.00	6.37	--	--	--	16000
	Max	27.69	109.70	8.12	8.29	35.40	53710	93.60	2500.00	11000.00	6.37	--	--	--	32000
	% exceed trigger	9.52	42.86	N/A	15.00	N/A	N/A	70.59	4.35	20.00	100.00	N/A	N/A	N/A	N/A
	Count	21	21	20	20	22	20	17	23	25	1	--	--	--	4
E-337	Mean	23.47	71.71	5.28	7.70	23.71	36835	15.86	637.65	1159.91	3.83	0.40	0.08	--	17750
	StDeV	5.05	21.88	1.74	0.58	10.59	15725	16.13	1919.62	3428.08	4.00	--	--	--	13175
	Median	24.65	65.90	4.54	7.71	26.83	41850	14.20	27.50	39.00	3.83	0.40	0.08	--	20500
	Min	14.00	22.70	2.21	6.07	0.29	627	0.80	0.00	1.00	1.00	0.40	0.08	--	0
	Max	31.29	106.30	8.83	8.39	35.02	53100	62.80	8100.00	14000.00	6.65	0.40	0.08	--	30000
	% exceed trigger	10.00	57.89	N/A	31.58	N/A	N/A	78.57	20.00	47.83	50.00	0.00	100.00	N/A	N/A
	Count	20	19	19	19	20	20	14	20	23	2	1	1	--	4
E-338	Mean	22.62	94.05	6.87	8.01	27.19	41101	23.09	43.39	219.96	1.14	0.25	0.08	0.04	25500
	StDeV	3.40	23.39	1.81	0.56	9.59	16159	34.49	165.36	1037.59	1.46	0.16	0.17	0.09	5323
	Median	23.53	92.70	6.70	8.15	31.27	48920	6.90	5.00	10.00	1.00	0.25	0.00	0.01	25500
	Min	13.86	52.60	3.90	6.20	6.51	4800	0.60	0.00	1.00	0.00	0.00	0.00	0.00	19000
	Max	28.39	140.30	11.50	8.87	44.63	65790	116.00	800.00	5200.00	7.19	0.62	0.56	0.33	32000
	% exceed trigger	4.55	47.62	N/A	14.29	N/A	N/A	61.11	4.35	8.00	4.35	0.00	40.00	30.77	N/A
	Count	22	21	20	21	21	19	18	23	25	23	24	10	13	4
E-711	Mean	22.78	81.89	5.85	7.57	29.05	44118.95	21.36	20.73	43.54	0.00	--	--	--	23666.67
	StDeV	4.21	19.42	1.49	0.87	7.43	10827.36	23.14	76.13	191.39	--	--	--	--	8020.81
	Median	24.60	86.50	5.99	7.89	32.53	49700.00	8.25	1.00	2.00	0.00	--	--	--	23000.00
	Min	12.82	42.90	2.98	5.58	15.03	24750.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	16000.00
	Max	29.05	109.60	8.13	8.33	35.57	53850.00	78.10	360.00	980.00	0.00	0.00	0.00	0.00	32000.00
	% exceed trigger	9.52	36.84	N/A	25.00	N/A	N/A	66.67	4.35	7.41	0.00	0.00	--	--	N/A
	Count	21	19	18	20	21	19	18	23	27	2	1	--	--	3

*Trigger value for enterococci is Risk of gastrointestinal illness (GI)<1%

6.1 Microbial Monitoring

A comparison of enterococci data from four recent years (2017, 2018, 2019 and 2020) to the NHMRC (2008) recreational guideline is summarised in Table 6-2.

Table 6-2 Summary of recreational water quality assessment.

Site	95th percentile (cfu/100ml)	NHMRC (2008) microbial assessment category	NHMRC (2008) risk of illness
E-336	56.8	B (41-200 cfu/100ml)	GI illness risk: 1-5% AFRI risk: 0.3-1.9%
E-337	228	C (200-501 cfu/100ml)	GI illness risk: 5-10% AFRI risk: 1.9-3.9%
E-338	27	A (≤40 cfu/100ml)	GI illness risk: <1% AFRI risk: <0.3%
E-711	6	A (≤40 cfu/100ml)	

AFRI = acute febrile respiratory illness; GI = gastrointestinal, NHMRC = National, Health and Medical Research Council. Not relevant = site was not assessed for recreational suitability were monitored to investigate potential sources of faecal pollution within Swan Lake.

6.2 Review of Pollution Sources within Catchment

A high-level review was undertaken to assess the potential influence on the catchment from human versus environmental sources of faecal contamination. Refer to Table 6-3.

Table 6-3 Review of faecal pollution sources with Berrara Creek.

Site Information	
Catchment land use	Relatively undisturbed (95% located in Conjola National Park) (DP&E 2022a).
Type of primary recreational activities	Swimming and kayaking.
Type of secondary recreational activities	Boating and fishing (limited).
Groups likely to use the site	All ages (including infants and elderly which are the vulnerable age groups) are likely to use the site for primary recreation.
Flushing	Detailed hydraulic information is not available. Berrara Creek is a tidal estuary that occasionally closes to the sea and the lower reaches have regular tidal oceanic flushing. Some information on openings of Berrara Creek is available (**Appendix A**), however this is only until 2001. Water quality monitoring of salinity suggests the lagoon has been flushed more regularly in recent years. There

Site Information	
	are higher salinity values measured in 2014 – 2020, compared to more lower and variable values in 2010 – 2013 (**Appendix D**).
Rainfall	The two highest enterococci values at E-336 (68 cfu/100ml on 4/5/17 and 40 cfu/100ml on 14/11/19) and E-337 (120 cfu/100ml on 4/5/17 and 300 cfu/100ml on 14/11/19) do not correspond to periods of significant rainfall (<5mm in the two preceding days). The measured values of 11,000 at E-336 and 14,000 at E-337 on 29/1/2013 were associated with a heavy rainfall event, with 138 mm of rainfall recorded at Bendalong on 29/1/2013.
Pollution Sources	
Bather shedding (i.e., shed from skin during bathing as source of faecal contamination, sunblock and other chemicals)	The number of bathers can be considered as a source of contamination. This is considered to be a small source as usage is generally limited due to the small size (0.3 km^2) of the estuary. Peak usage is expected to occur by tourists during school holidays and summer (Dec - Feb).
Toilet facilities	Unknown.
Wastewater Treatment Plants	N/A
Designated sewage overflows (including network)	Sewage pump station (SPS 16) is adjacent to Berrara Creek and monitoring site E-337. Occasional overflows of sewage have previously occurred.
Wastewater re-use area	Not known.
Stormwater & urban runoff	The drainage line between Waterhaven Avenue and Meadowlake Avenue which has been identified as a historical source of faecal contamination related to urban and stormwater runoff.
Tributaries	N/A
Boats	Boating with peak use during school holidays and summer.
Animals/Environment	95% of the catchment is within Conjola National Park which is heavily forested to the banks of the lagoon. Faecal contamination from the upper reaches of Berrara Creek are likely to be predominantly environmental sources such as from birds and native animals. Rotting vegetation would be a source of increased nutrient input

Site Information	
	and may also be associated with faecal contamination if the vegetation itself was contaminated by this material. Domestic dogs in the lower catchment (associated with the residential and tourism land uses) are a potential source of faecal contamination from the foreshore reserves and beaches No agricultural livestock within catchment.
Management Controls in place	
Management controls	Ongoing faecal coliform and enterococci monitoring. Storage capacity of emergency overflow point (SPS 16) is planned to be upgraded in line with expected population growth. CMP management actions (to be developed). Dogs and camping are prohibited from the entrance foreshore reserve but not all foreshore reserves.
Management response plan for exceptional events (such as sewage overflows)	Pollution Incident Response Management Plan (PIRMP).

6.3 Overall Assessment

Recreational water quality within Berrara Creek continues to be highly ranked as "Good" (4 stars out of 4) for swimming and other water-based activities based on the NHRMC (2008) guidelines at the mouth of the estuary and upstream (near Fishermans Rock Road Crossing).

The microbial monitoring combined with review of contamination sources, suggests sources of faecal contamination within the Berrara Creek catchment for monitoring sites E-336 and E-337. The drainage line that runs between Waterhaven Avenue and Meadowlake Avenue (E-337) is located within this drainage line at the point of entry to Berrara Creek, and E-336 is located ~50 m upstream. These have previously been identified as a source of contamination and historically have shown elevated levels of faecal contamination.

Enterococci levels appear to have reduced over time, noting the limited dataset and that elevated values in 2013 and 2014 may have been measured during a pollution event (i.e. in 2013 and 2014 values of up to 14,000 cfu/100ml were reported for enterococci). The recent dataset also includes an extended drought period with lower runoff and stormwater resulting in less contamination to the waterway. The higher enterococci results during 2013 may have also been associated with less oceanic flushing as there was lower and more variable salinity levels during these years (see Section 3.4).

The NHMRC (2008) microbial assessment categories of B (41-200 cfu/100ml) and C (200-501 cfu/100ml) for these sites (see Table 6-2) suggest that there is a slightly higher risk of illness associated with recreation at these monitoring sites, particularly for primary recreational activities (e.g. swimming). Further, enterococci results from monitoring sites E-338 and E-711 suggest that the dilution and flushing within Berrara Creek continues to be sufficient to maintain recreational water quality in the upper and lower reaches of Berrara Creek, which are more likely to be used for primary recreation. This is similar to the findings of historical assessments (Shoalhaven City Council 2002). Site E-711 is also located some distance from residential areas and would be less impacted by surface runoff and stormwater inputs than sites E-336 and E-337. Similarly, site E-338 would be expected to have a greater degree of mixing with ocean waters resulting in these findings of higher water quality.

Overall, on the basis of microbial monitoring and review of faecal contamination sources, the recreational quality of Berrara Creek is considered to be good and suitable for identified primary and recreational activities in most areas, with areas near the drainage recommended to be avoided, especially during wet weather. The general advice from NHMRC (2008) applies to the entire area - that swimming should be avoided for at least 3 days following rainfall in rivers, lakes and estuarine systems.

7 Summary

7.1 Estuary Health and Water Quality Issues

A summary of the water quality issues for Berrara Creek, and potential implications is provided in Table 7-1.

The next stage of the CMP will include development of an management actions to address identified water quality issues and meet water quality objectives. This will include a recommended monitoring program with a summary of the locations, frequency, parameters, sampling methodology, limits of reporting (LORs) and applicable guideline values.

Table 7-1 Water quality issues and implications.

Issue	Implication and Indicative Management Responses
Water Quality Program – data collection, maintenance and reporting	
Routine water quality has been collected for Berrara Creek. There are some inconsistencies with sampling and data entry including: ▪ Inconsistent seasonal sampling replication (e.g. less sampling has occurred in winter months). ▪ Inconsistent approach to reporting values below the estimated quantification limit (EQL). ▪ Ambiguous values that were likely related to data entry and/or instrument errors. ▪ Potential overestimation of turbidity. ▪ The Aqua data portal dataset includes both pollution events and routine monitoring data. However, these cannot be identified or separated (apart from reviewing and aligning historical rainfall data). ▪ If the Council wishes to include estuary health assessments in future monitoring for Berrara Creek, then consistent sampling of turbidity and chlorophyll-*a* (at minimum) is required at representative sites.	Not having consistent and reliable water quality data affects the ability to assess water quality health, whether water quality objectives are being met and thus ability to make management decisions. A lack of similarity / consistency in data collection and therefore in datasets between years restricts the analysis which can be undertaken, for example between seasons, years or events. Errors in water quality data can carry over into reporting issues if not identified (i.e. such as parameters where values are unusually low or high but within possible range such as elevated turbidity throughout dataset). Inconsistencies with reporting values <EQL makes it difficult to compare at later stages. Reduced ability to discriminate between pollution and routine data can affect interpretation of results.
Limited nutrient monitoring and chlorophyll-a data within Berrara Creek	
Increasing the number of sites that are monitored for nutrients and chlorophyll-*a* will better assist in understanding trends and linking these to ecological risk. The limited available nutrient and chlorophyll-*a* dataset suggests that most samples are below the DP&E MER guideline values for nutrients in lagoons.	Not having an adequate dataset can affect ability to assess water quality health and whether objectives are being met. Nutrient over enrichment (nitrogen and phosphorous, particularly bioavailable forms) can cause excessive nuisance plant and algae growth and lead to low DO and altered pH. In addition, this can lead to human health, amenity and ecological risks.
Elevated turbidity and reduced DO within Berrara Creek.	

Issue	Implication and Indicative Management Responses
Turbidity and DO within Berrara Creek are often outside of the suitable ranges (guidelines). Turbidity in all four sites was generally elevated and above the applicable guideline level. This presents potential risks to water quality within the basin, although historical data suggests this is not apparent. Turbidity values could be overestimated, and the method could be reviewed. Within the creek hydrodynamics are important factors. The high flushing rate and dilution capacity assists within maintaining water quality in the creek.	Elevated turbidity and reduced DO can result in impacts on ecological functioning which during extreme prolonged events can cause fish kills. Erosion and urban runoff have previously been identified as issues within the lagoon.
Faecal contamination sources (the drainage line between Waterhaven Avenue and Meadowlake Avenue)	
The drainage line between Waterhaven Avenue and Meadowlake Avenue continues to be a source of faecal pollution. The 95%ile enterococci levels placed the two monitoring sites near Berrara and the drainage line within category C and D, which indicate these sites have a slightly increased risk of illness associated with recreation. However, recreational water quality within the other monitoring sites in Berrara Creek (which are located further upstream away from residential areas and near the mouth of the lagoon) corresponded to Category A, suggesting that the high dilution and flushing rates of the basin are sufficient to maintain recreational quality in these areas despite catchment inputs. Overall recreational quality can be considered to be good.	Potential reduced recreational quality due to increased risk of illness. Potential impacts on recreational water quality within other areas of the lagoon are considered a low risk due to regular flushing and historical monitoring results. Managing these sources of faecal contamination is important. The general advice from NHMRC (2008) applies - that swimming should be avoided for at least 3 days following rainfall in rivers, lakes and estuarine systems. It is recommended that all enterococci sampling is paired with a sanitary inspection as undertaken for Beachwatch sites using the DPIE (2020b) template (see Appendix F).
Sea level rise and climate change	
Potential impacts on water quality through changes to the hydrodynamics of the estuary and more frequent extreme weather events (e.g., drought and heavy rainfall).	Impacts on hydrodynamic and ecological processes within the estuary affecting water quality (such as changes in pH and temperature). Sea level rises will likely increase shoreline erosion resulting in increased organic matter, suspended sediments and debris. Potential implications for ecological health via inundation of infrastructure and endangered ecological communities are loss of macrophytes and/or landward migration of saltmarsh, mangroves and changes to seagrass distribution. More frequent disturbances affect the resilience of ecosystems and may result in longer term trends of continued decline of estuarine biodiversity.

Issue	Implication and Indicative Management Responses
Management of catchment inputs	
The lower three kilometres of the lagoon normally behaves as a tidal estuary, however, the mouth of the lagoon does occasionally naturally close to the sea.	Impacts on hydrodynamics and ecological processes within the estuary. Closure of the opening does not translate to poorer water quality. Water quality is more influenced by catchment inputs. For example, during the 2019-2020 bushfires when there was a buildup of debris at the entrance.
Impacts on water quality following bushfires (2019-2020)	
Increased catchment runoff and associated sediment and nutrients and debris from burnt areas after the bushfires.	Bushfires can impact on water quality with key changes including increased sediment and nutrient loads (especially total organic carbon and dissolved carbon) and increased turbidity, which in turn can generate algae blooms where die off can raise pH and reduce DO (NSW EPA 2020). Increases in suspended solids and turbidity can smother seagrasses resulting in a decline in available habitat for species (i.e. fish).

7.2 Recommended Sampling Program

7.2.1 Water Quality

Recommended monitoring sites for inclusion in future sampling is shown in Figure 7-1 and a summary of the recommended program is provided in Table 7-2.

Improvements to ongoing monitoring will ensure that the program can track improvements towards meeting current water quality objectives.

If the Council wishes to include estuary health, then additional monitoring would be required. Estuary health monitoring should be coordinated with the existing DP&E three-year rotational schedule for estuaries across the state. This would consist of sampling approximately every 3 weeks within the identified chlorophyll-*a* maximum period of mid-November to end of March at the monitoring sites A and E-711. This equates to a minimum of 6 sampling occasions which is recommended within the DP&E guidelines (OEH, 2016) for statistical analysis. At a minimum this would include turbidity and chlorophyll-*a,* however it is recommended that all parameters listed in the table are included in the estuary health assessment.

The recommendations are as follows:

- Recommended monitoring sites as indicators of estuary health.
- Continuing to monitor faecal coliforms and enterococci as indicators of recreational quality for primary and secondary recreational activities.
- Reducing the number of monitoring sites. Monitoring sites around the shoreline (i.e. E-336) have been recommended for exclusion as these may not be representative of the estuary and representing localised issues (i.e., elevated enterococci associated with diffuse

runoff and nutrients associated with sediment resuspension). These sites are also not used in the estuary health program. Site E-338 has been retained, as this site is a popular swimming area.

- Increasing sampling frequency to provide stronger statistical significance from the monitoring program.
  - Sampling during summer and spring. This is recommended to be undertaken monthly for physicochemistry and pathogens, once every 3 weeks for chlorophyll-*a* and turbidity, and once per season for nutrients and suspended sediments.
  - Monitoring sites around the shoreline have been recommended for exclusion as these may not be representative of the estuary.
  - Continuing to monitor physicochemistry, chlorophyll-*a* and nutrients across all recommended monitoring sites as indicators of estuary health.
- Continuing to monitor faecal coliforms and enterococci as indicators of recreational quality for primary and secondary recreational activities.
- Undertake water quality sampling following wet weather or pollution events focusing on E-337 to continue to investigate impacts associated with the drainage line between Waterhaven Avenue and Meadowlake Avenue.

  This is particularly important for enterococci. It is recommended that an appropriate trigger for wet weather sampling is developed (for example, >75mm combined rainfall in three days). It's important that this information is stored alongside the monitoring data.
- Enterococci sampling is paired with a sanitary inspection if enterococci values are high, as undertaken for Beachwatch sites using the DPIE (2020b) template (https://www.environment.nsw.gov.au/research-and-publications/publications-search/protocol-appendix-a-sanitary-inspection-report, see Appendix F).

DP&E water quality guidelines for lagoons outlined in Section 2.3.1 are recommended for comparison to ongoing water quality monitoring.

Figure 7-1 Recommended monitoring sites for ongoing water quality sampling. Blue = recommended for inclusion; red = recommended for exclusion. Note: site A is from the DP&E estuary health program.

Table 7-2 Summary of proposed water quality program for Shoalhaven City Council

Parameter	LOR	Frequency	Sites	Rationale
Physicochemistry				
pH	--	Council monitoring monthly during summer. Council monitoring once each during other seasons winter, autumn and spring (i.e 3 sampling occasions) with boat based transect sampling . DPE Estuary Health Assessment[2] Every 3 years, measure every 3 weeks during November to March (i.e. 6 sampling occasions) with boat based transect sampling Event sampling[1] as required	E-711, A	Estuary health within basin.
Temperature	0.1 °C			
Salinity	ppt			
Electrical conductivity	µS/cm			
Turbidity	0.1 ntu			
DO	0.1 mg/L			

Parameter	LOR	Frequency	Sites	Rationale
Algae				
Chlorophyll-*a*	0.5 mg/m^3	Council monitoring every three weeks during summer (minimum 6 samples between November – March). Once each during other seasons winter, autumn and spring (i.e 3 sampling occasions). Event sampling[1] DPE Estuary Health Assessment[2] Every 3 years, measure every 3 weeks during November to March (i.e. 6 sampling occasions). .	E-711, A	Estuary health within basin.
Nutrients				
TN	0.025 mg/L	Council monitoring once during each season. Event sampling[1]	E-711, A	Estuary health within basin. As key indicators to measure erosion improvements works.
TP	0.005 mg/L			
Pathogens				
Enterococci	1 CFU/100ml	Council monitoring monthly during swimming seasons (spring, summer and autumn). Event sampling[1]	E-711, E-338, E-337[1],	Recreational water quality within basin.
Faecal coliforms	1 CFU/100ml			
Suspended sediments				
TDS	0. 1 mg/L	Council monitoring once during each season. Event sampling[1]	E-711, A, E-337[1]	As key indicators to measure erosion improvements works.
TSS	0.1 mg/L			

LOR = limit of reporting. 1= to investigate potential impacts on water quality during events where elevated enterococci or other water quality parameter readings are recorded, 2= For the DPE estuary health assessment every 3 years, undertake 3 weekly monitoring of parameters (turbidity and chlorophyll-*a* as minimum) during November to March.

7.2.2 Ecological Health

Updated macrophyte mapping would be useful to enable assessment of Berrara Creek estuary health, noting the limitations in comparisons between historical data (i.e. 1982 and 2005). Advice from NSW DPI indicates that at present, Berrara Creek is not listed for repeated macrophyte mapping over time.

It is also recommended that records are maintained of the estuary openings as this information will assist with interpretation of the water quality and macrophyte mapping information. This could be done by retention of the temporary water level recorder that has been recently installed to assess long-term water levels and allow analysis of creek tidal characteristics and assessment of closure events on an as-needs basis, as well as monitoring of entrance conditions by Council staff on a regular basis, including survey of berm levels and documentation of closure and breaching events.

Estuary health monitoring should be coordinated with Council, DP&E, NSW DPI, existing monitoring and mapping programs.

8 References

Advisian (2019). Shoalhaven CMP Scoping Study. A report produced for Shoalhaven City Council by Advisian.

Anderson, M., Gorley, R., and Clarke, K. R. (2008). PERMANOVA+ for PRIMER: guide to software and statistical methods. Primer-e, Plymouth, UK, 32.

ANZECC (2000). Guidelines for Fresh and Marine Water Quality, Oct 2000. Australian and New Zealand Environment & Conservation Council / Agriculture and Resource Management Council of Australia and New Zealand (2000).

ANZG (2018). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines.

Burns, C. and Davey, G. (2010). Oceans of Life – ours to explore; ours to restore. http://www.mesa.edu.au/seaweek2010/saltmarsh.asp.

Creese, R.G., Glasby, T.M., West, G., and Gallen, C. (2009). Mapping the habitats of NSW estuaries. Industry & Investment NSW, Nelson Bay, Australia, 95pp.

DEC (2005). Water Quality Objectives for the estuaries on the NSW South Coast. Available from: https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Water/Water-quality/marine-water-quality-objectives-nsw-ocean-waters-south-coast-05582.pdf?la=en&hash=4C2F104FAE1B284A85B033D00A828EE1024BA474. NSW Department of Environment and Conservation (DEC).

DP&E (2022a). Berrara Creek Estuary Health and Features. Available from: https://www.bing.com/newtabredir?url=https%3A%2F%2Fwww.environment.nsw.gov.au%2Ftopics%2Fwater%2Festuaries%2Festuaries-of-nsw%2Fberrara-creek. NSW Department of Planning and Environment (DP&E). Accessed in February 2022.

DP&E (2022b). Review of the NSW Water Quality Objectives. Available from: Review of the NSW Water Quality Objectives. NSW Department of Planning and Environment (DP&E). Accessed in February 2022.

DP&E (2022c). Berrara Creek Water Quality Monitoring. Available from: Berrara Creek | NSW Environment, Energy and Science. NSW Department of Planning and Environment (DP&E). Date Accessed: March 2022.

DP&E / Shoalhaven City Council (in preparation at time of reporting in March 2022). Shoalhaven City Council Estuary Health Report Cards 2020-2021 (including DP&E MER Guidelines). NSW Department of Planning and Environment (DP&E).

DPIE (2016). NSW Natural Resources Monitoring, Evaluation and Reporting Program. Available from: Assessing estuary ecosystem health: Sampling, data analysis and reporting protocols | NSW Environment, Energy and Science. NSW Department of Planning, Infrastructure and Environment (DPIE).

DPIE (2020a). State of the beaches 2019-2020 - South Coast region. Available from: https://www.environment.nsw.gov.au. NSW Department of Planning, Infrastructure and Environment (DPIE).

DPIE (2020b) Sanitary Inspection Report template for beaches and estuaries. Available from: Protocol – Appendix A: Sanitary inspection report | NSW Environment and Heritage. Accessed: June 2022.

Evans K., Bax N., Bernal P. et al. (eds), (2016). The first global integrated marine assessment: world ocean assessment 1, United Nations, New York.

Marine Spatial Planning (2009). A Step-by-Step Approach towards Ecosystem-based Management. https://www.mspglobal2030.org/wp-content/uploads/2019/03/Marine-spatial-planning-a-step-by-step-approach.pdf.

Minitab 17 Statistical Software (2010). [Computer software]. State College, PA: Minitab, Inc. (www.minitab.com).

NHMRC (2008). Guidelines for Managing Risks in Recreational Water. Australian Government, February 2008. National Health and Medical Research Council (NHMRC).

NSW DPI (2002). Critical Habitat of Grey Nurse Shark. https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/636330/Grey-nurse-shark-critical-habitat.pdf. NSW Department of Primary Industries (DPI).

NSW DPI (2021). Marine Protected Areas. https://www.dpi.nsw.gov.au/fishing/habitat/protecting-habitats/mpa. NSW Department of Primary Industries (DPI).

NSW DPI (2022) Estuarine Habitat Dashboard and Change Analysis Tool. Available online: NSW Estuarine Mapping (shinyapps.io). NSW Department of Primary Industries (DPI). Date Accessed: March 2022.

NSW NPWS (2009). Conjola National Park Plan of Management. https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Parks-reserves-and-protected-areas/Parks-plans-of-management/conjola-national-park-plan-of-management-090329.pdf. NSW National Parks and Wildlife Service (NPWS).

NSW NPWS (2021). Conjola National Park. https://www.nationalparks.nsw.gov.au/visit-a-park/parks/conjola-national-park/map. NSW National Parks and Wildlife Service (NPWS).

NSW Rural Fire Service (2020). Unprecedented season breaks all records. Bush Fire Bulletin. Sydney: NSW Rural Fire Service. 42 (1): 3. ISSN 1033-7598.

OEH (2016). Assessing estuary ecosystem health: Sampling, data analysis and reporting protocols. NSW Natural Resources Monitoring, Evaluation and Reporting Program. Available from: Assessing estuary ecosystem health: Sampling, data analysis and reporting protocols (nsw.gov.au).

Ridgway K.R. and Dunn J.R. (2003). Mesoscale structure of the mean East Australian Current system and its relationship with topography. Progress in Oceanography 56:189–222.

Roper, T. Creese, B. Scanes, P. Stephens, K. Williams, R. Dela-Cruz, J. Coade, G. and Coates, B. (2011). Assessing the condition of estuaries and coastal lake ecosystems in NSW Technical Report - NSW State of the Catchments 2010. NSW Office of Environment and Heritage, Sydney. Downloaded 15th January 2012 from: http://www.environment.nsw.gov.au/resources/soc/20110717EstuariesTRS.pdf.

Shoalhaven City Council (2002). Swan Lake and Berrara Creek Natural Resources Management Strategy. Available from: Swan Lake and Berrara Creek Natural Resources Management Strategy (nsw.gov.au).

Shoalhaven City Council (2021). Bushfire Affected Coastal Waterways. Available from: Bushfire Affected Coastal Waterways | Get Involved Shoalhaven (nsw.gov.au). Accessed February 2022.

Sturrock, K., and Rocha, J. (2000). A Multidimensional Scaling Stress Evaluation Table. Field Methods, 12(1), 49–60.

West, G., and Glasby, T.M., (2021). Interpreting long-term patterns of seagrasses abundance: how seagrass variability is dependent on genus and estuary type. Estuaries and Coasts.

West, R.J., Thorogood, C.A., Walford, T.R. and Williams R.J. (1985). An estuarine inventory for New South Wales, Australia. Fisheries Bulletin 2. Department of Agriculture, New South Wales. 140 pp.

Appendix A
Summary of Berrara Creek Openings

Table 8-1 Summary of known openings of Berrara Creek between 1996 to 2001

Opening	Closure date	Natural/Artificial	Source of information	Duration
N/A	21/03/1996	Unknown	Swan Lake & Berrara Creek Natural Resources Management Strategy, SCC, Dec. 2002. p. 14.	N/A
13/04/1996	15/05/1996	Unknown	Swan Lake & Berrara Creek Natural Resources Management Strategy, SCC, Dec. 2002. p. 14.	32 days
19/06/1996	25/06/1996	Unknown	Swan Lake & Berrara Creek Natural Resources Management Strategy, SCC, Dec. 2002. p. 14.	6 days
1/09/1996	28/12/1996	Unknown	Swan Lake & Berrara Creek Natural Resources Management Strategy, SCC, Dec. 2002. p. 14.	118 days
3/02/1997	5/02/1997	Unknown	Swan Lake & Berrara Creek Natural Resources Management Strategy, SCC, Dec. 2002. p. 14.	2 days
13/02/1997	25/02/1997	Unknown	Swan Lake & Berrara Creek Natural Resources Management Strategy, SCC, Dec. 2002. p. 14.	12 days
1/03/1997	1/06/1997	Unknown	Swan Lake & Berrara Creek Natural Resources Management Strategy, SCC, Dec. 2002. p. 14.	92 days
28/06/1997	15/03/1998	Unknown	Swan Lake & Berrara Creek Natural Resources Management Strategy, SCC, Dec. 2002. p. 14.	260 days
19/05/1998	15/04/2000	Unknown	Swan Lake & Berrara Creek Natural Resources Management Strategy, SCC, Dec. 2002. p. 14.	697 days
6/05/2000	16/08/2000	Unknown	Swan Lake & Berrara Creek Natural Resources Management Strategy, SCC, Dec. 2002. p. 14.	102 days
22/11/2000	10/01/2001	Unknown	Swan Lake & Berrara Creek Natural Resources Management Strategy, SCC, Dec. 2002. p. 14.	49 days
30/01/2001	28/02/2001	Unknown	Swan Lake & Berrara Creek Natural Resources Management Strategy, SCC, Dec. 2002. p. 14.	29 days
12/09/2001	20/10/2001	Unknown	Swan Lake & Berrara Creek Natural Resources Management Strategy, SCC, Dec. 2002. p. 14.	38 days

Berrara Creek was artificially opened by community during 2020 following the 2019/20 bushfires and high water levels, most likely in February 2020 following flooding. There was a significant build up of bushfire debris at the entrance.

Other information on Berrara Creek openings is not available after 2001, although this would have occurred throughout this period.

Table 8-2 Entrance state from satellite imagery, 2004 – 2023 (Nearmap.com, Google Earth)

Satellite Image Date	Entrance Open/Closed	Source of information
1/2/2004	Open	Google Earth
13/7/2004	Closed	Google Earth
19/8/2009	Closed	Google Earth
6/9/2011	Open	Google Earth
21/12/2011	Closed	Google Earth
11/10/2013	Open	Google Earth
10/8/2015	Open	Nearmap.com
23/10/2015	Open	Google Earth
17/11/2015	Open	Google Earth
17/1/2016	Open	Google Earth
13/2/2016	Open	Google Earth
24/2/2016	Open	Google Earth
31/3/2016	Open	Google Earth
14/8/2016	Open	Nearmap.com
5/6/2017	Open	Nearmap.com
13/9/2017	Open	Nearmap.com
5/2/2018	Open	Nearmap.com
6/5/2018	Open	Nearmap.com
22/7/2018	Closed	Nearmap.com
29/9/2018	Closed	Google Earth
1/12/2018	Closed	Nearmap.com
26/4/2019	Closed	Nearmap.com
1/8/2019	Closed	Nearmap.com
14/9/2019	Closed	Nearmap.com
27/10/2019	Closed	Nearmap.com

Satellite Image Date	Entrance Open/Closed	Source of information
13/3/2020	Open	Nearmap.com
17/8/2020	Open	Nearmap.com
7/9/2020	Open	Nearmap.com
9/12/2020	Open	Nearmap.com
1/4/2021	Open	Nearmap.com
22/4/2021	Open	Nearmap.com
17/8/2021	Open	Nearmap.com
15/12/2021	Open	Nearmap.com
14/2/2022	Open	Google Earth
20/3/2022	Open	Nearmap.com
16/4/2022	Open	Nearmap.com
7/5/2022	Open	Nearmap.com
24/6/2022	Open	Nearmap.com
30/7/2022	Open	Nearmap.com
30/10/2022	Open	Nearmap.com
9/12/2022	Open	Google Earth
2/2/2023	Open	Nearmap.com

Appendix B
Water Quality Data from 2010-2021

				Field							Biological		Algae indicator	Nutrients			Other
				Temperature	Dissolved Oxygen (% Saturation)	Dissolved Oxygen	pH	Salinity	Electrical Conductivity	Turbidity	Faecal Coliforms	Enterococci	Chlorophyll a	Nitrogen	Total Phosphorus	Total Phosphorus as P (Organic Phosphate as P)	TDS
		EQL		0.1	0.1	0.1	0.1		100	0.1	1	1	0.5	0.025	0.005	0.005	
		NSW DPIE MER Triggers - Lagoons			76-107		7.5-8.9			4.4			3.9	0.625	0.025	0.01	
		NHRMC (2008) Primary contact recreational		15-35							median 150	median < 35					
Area	Field ID	Date	Season	°C	%	mg/L	-	ppt	µS/cm	ntu	CFU/100mL	cfu/100mL	mg/m3	mg/L	mg/L	mg/L	mg/L
Berrara Creek	E-336	23/02/2010	Summer	27.57	73.2	4.96	7.3	27.06	42180	6.7	3		6.37				32000
Berrara Creek	E-336	22/06/2010	Winter	13.67	92.9	7.89		32.66	49910	18.9	140	42					26000
Berrara Creek	E-336	5/10/2010	Spring	20.78	69.2	5.3	8.11	26.54	41440	16.3	0	0					23000
Berrara Creek	E-336	17/01/2011	Summer	26.68	80.8	5.7	7.73	22.67	35960	17.7		170					
Berrara Creek	E-336	29/03/2011	Autumn	24.45	88.8	6.6	7.56	20.6	33000	0.1		10					
Berrara Creek	E-336	1/11/2011	Spring	22.69	48.8	3	7.89	15.51	25500	1.2		10					16000
Berrara Creek	E-336	14/11/2011	Spring	27.69	83.1	6.01	7.81	14.96	24640	5.1	9	1					
Berrara Creek	E-336	17/01/2012	Summer	25.08	46.7	3.5	7.14	16.69	16690	2.7	0	0					
Berrara Creek	E-336	28/05/2012	Autumn	12.55			7.83	21.1	33700	3.7	3	1					
Berrara Creek	E-336	29/01/2013	Summer	24.77	63.1	4.81	8.21	14.78	24370	93.6	2500	11000					
Berrara Creek	E-336	21/01/2014	Summer	24.52	81.9	5.57	8.04	35.4	53710		76	46					
Berrara Creek	E-336	30/04/2014	Autumn	20.84	81.6	6	7.81	32.202	49300		24	17					
Berrara Creek	E-336	12/11/2014	Spring	23.33	99.9	7	8.28	34.59	52500	7							
Berrara Creek	E-336	12/11/2014	Spring								22	27					
Berrara Creek	E-336	18/05/2015	Autumn								1	19					
Berrara Creek	E-336	24/11/2015	Spring		78	4.8	7.95	35.29	53500								
Berrara Creek	E-336	24/11/2015	Spring								1	3					
Berrara Creek	E-336	5/04/2016	Autumn	26.4	74	4.9		34.8	52800								
Berrara Creek	E-336	6/04/2016	Autumn	26.4	74	4.9	8.29	34.8	52800								
Berrara Creek	E-336	6/04/2016	Autumn								1	1					
Berrara Creek	E-336	21/11/2016	Spring	24.73	109.7	7.57	6.19	32.52	49730	5.1							
Berrara Creek	E-336	21/11/2016	Spring								2	12					
Berrara Creek	E-336	4/05/2017	Autumn								40	68					
Berrara Creek	E-336	21/11/2017	Spring	26.01	49.6	3.37	8.27	31.46	48280	71.1							
Berrara Creek	E-336	21/11/2017	Spring								2	4					
Berrara Creek	E-336	17/09/2018	Spring								1	1					
Berrara Creek	E-336	19/09/2018	Spring	17.75	105	8.12	7.64	34.73	52570	5.9							
Berrara Creek	E-336	3/12/2018	Summer	23.34	101.6	7.4	7.55	27.16		1.6							
Berrara Creek	E-336	3/12/2018	Summer								2	3					
Berrara Creek	E-336	11/04/2019	Autumn	20.08	106.1	7.82	7.93	35.39	53610	49.3							
Berrara Creek	E-336	11/04/2019	Autumn								1	1					
Berrara Creek	E-336	14/11/2019	Spring								77	40					
Berrara Creek	E-336	15/04/2020	Autumn								8	5					
Berrara Creek	E-336	23/11/2020	Spring	25	78.8		8.07	14.64		30.8	18	11					
Berrara Creek	E-336	15/04/2021	Autumn								9	2					
Berrara Creek	E-337	23/02/2010	Summer	26.79	46.4	3.19	7.13	26.69	41650	5.8	120		6.65				30000
Berrara Creek	E-337	22/06/2010	Winter	14.6	64.3	5.45		30.03	46310	62.8		1700					0
Berrara Creek	E-337	5/10/2010	Spring	16.46	22.7	2.21	7.23	0.29	627	18.4	52	2					25000
Berrara Creek	E-337	17/01/2011	Summer	25.67	57	4.05	7.71	24.68	38820	21		370	1	0.4	0.08		
Berrara Creek	E-337	29/03/2011	Autumn	23.77	88.5	7	7.52	12.26	20500	1.3		4					
Berrara Creek	E-337	1/11/2011	Spring	22.41	51.9	4.1	8.19	15.71	25800	0.8		39					16000
Berrara Creek	E-337	14/11/2011	Spring	29.08	100	7.06	7.92	15.08	24830	10	39	7					
Berrara Creek	E-337	17/01/2012	Summer	25.29	59.4	4.4	7.23	16.81	27400	2	0	8					
Berrara Creek	E-337	28/05/2012	Autumn	14			8.2	20.74	33200	21.6	50	42					
Berrara Creek	E-337	29/01/2013	Summer	24.01	106.3	8.83	8.25	2.23	3792		3500	14000					
Berrara Creek	E-337	21/01/2014	Summer	26.08	62.6	4.54	7.26	19.42	31250		8100	9500					
Berrara Creek	E-337	12/11/2014	Spring	23.65	81.1	5.7	8.01	31.48	48300	7							
Berrara Creek	E-337	12/11/2014	Spring								420	160					
Berrara Creek	E-337	18/05/2015	Autumn								1	49					
Berrara Creek	E-337	24/11/2015	Spring	30.09	58.1	3.8	7.61	29.02	43500								
Berrara Creek	E-337	24/11/2015	Spring								280	250					

				Field								Biological		Algae indicator	Nutrients			Other
				Temperature	Dissolved Oxygen (% Saturation)	Dissolved Oxygen	pH	Salinity	Electrical Conductivity	Turbidity	Faecal Coliforms	Enterococci	Chlorophyll a	Nitrogen	Total Phosphorus	Total Phosphorus as P (Organic Phosphate as P)	TDS
			EQL	0.1	0.1	0.1	0.1		100	0.1	1	1	0.5	0.025	0.005	0.005	
Berrara Creek	E-337	5/04/2016	Autumn	25.78	65.9	4.4	8.34	35.02	53100								
Berrara Creek	E-337	6/04/2016	Autumn	25.78	65.9	4.4	8.34	35.02	53100								
Berrara Creek	E-337	6/04/2016	Autumn								13	8					
Berrara Creek	E-337	21/11/2016	Spring	31.29	89.5	5.55	6.07	32.21	49300	25.3							
Berrara Creek	E-337	21/11/2016	Spring								1	5					
Berrara Creek	E-337	4/05/2017	Autumn								80	120					
Berrara Creek	E-337	21/11/2017	Spring	26.67	60.7	4.08	8.39	30.98	47610								
Berrara Creek	E-337	21/11/2017	Spring								14	5					
Berrara Creek	E-337	17/09/2018	Spring								1	1					
Berrara Creek	E-337	19/09/2018	Spring	16.12	94.7	7.56	7.61	34.62	52580	22.9							
Berrara Creek	E-337	3/12/2018	Summer	23.71	85.9	6.22	7.28	26.97	42050	4.8							
Berrara Creek	E-337	3/12/2018	Summer								51	81					
Berrara Creek	E-337	11/04/2019	Autumn	18.19	101.5	7.77	7.94	34.93	52980	18.4							
Berrara Creek	E-337	11/04/2019	Autumn								16	20					
Berrara Creek	E-337	14/11/2019	Spring								2	300					
Berrara Creek	E-337	15/04/2020	Autumn								7	5					
Berrara Creek	E-337	15/04/2021	Autumn								6	2					
Berrara Creek	E-338	23/02/2010	Summer	27.23	105.3	7.21	7.63	26.28	41080	36.5	10		7.19				32000
Berrara Creek	E-338	22/06/2010	Winter	13.86	83.5	7.04		33.07	50480	116	0	29	0	0	0		26000
Berrara Creek	E-338	5/10/2010	Spring	22.68	70.4	5.22	8.48	26.02	40710	16.2	8	4	3	0.5	0.12		25000
Berrara Creek	E-338	17/01/2011	Summer	24.36	128.5	9.3	8.39	25.19	39550	6.1		60					
Berrara Creek	E-338	29/03/2011	Autumn	23.53	140.3	11.5	7.95	6.51	11500	0.6		18	1	0.3	0		
Berrara Creek	E-338	1/11/2011	Spring	24	52.6	3.9	8.15	20.58	32900	1.3		10	0	0.5	0		19000
Berrara Creek	E-338	14/11/2011	Spring	28.39	90.7	6.37	8.15	18.1	29310	27.7	49	4	1	0.5	0		
Berrara Creek	E-338	17/01/2012	Summer	25.29	62.4	4.7	7.22	16.83	27400	1.3	0	8	0	0.4	0.04		
Berrara Creek	E-338	28/05/2012	Autumn	16.34			7.82	31.27	4800	2.1	21	25	0	0.3	0.56		
Berrara Creek	E-338	29/01/2013	Summer	24.45	128.6	8.31	8.49	44.63	65790	99.6	800	5200		0.2	0		
Berrara Creek	E-338	21/01/2014	Summer	23.34	91.2	6.32	8.1	35.72	54060	18.3	30	10		0.2	0.066		
Berrara Creek	E-338	30/04/2014	Autumn	21.9	92.7	6.7	7.97	33.52	51100	7.3	8	12	0	0	0		
Berrara Creek	E-338	12/11/2014	Spring	21.94	93.6	6.7	8.31	34.9	53000	3.5							
Berrara Creek	E-338	12/11/2014	Spring								5	14	1	0.25		<0.05	
Berrara Creek	E-338	18/05/2015	Autumn								1	10	1	0.1		0.01	
Berrara Creek	E-338	24/11/2015	Spring	24.75	79.3	5.4	8.17	34.91	53000								
Berrara Creek	E-338	24/11/2015	Spring								3	10	1	0.05		0.01	
Berrara Creek	E-338	5/04/2016	Autumn	23.86	75.3	5.9	8.34	12.32	20600								
Berrara Creek	E-338	6/04/2016	Autumn	23.86	75.3	5.9	8.34	12.32									
Berrara Creek	E-338	6/04/2016	Autumn								4	12	1	0.25		0.01	
Berrara Creek	E-338	21/11/2016	Spring	23.53	104.8	7.4	6.2	31.93	48920	4.3							
Berrara Creek	E-338	21/11/2016	Spring								1	5	1	0.2		0.01	
Berrara Creek	E-338	4/05/2017	Autumn								24	27	1	0.3		0.04	
Berrara Creek	E-338	21/11/2017	Spring	21.83	66.7	4.83	8.87	32.78	50080								
Berrara Creek	E-338	21/11/2017	Spring								1	1	1	0.25		0.33	
Berrara Creek	E-338	17/09/2018	Spring								1	1	1	0.219		0.026	
Berrara Creek	E-338	19/09/2018	Spring	17.54	105.4	8.18	7.71	34.82	52850	6.5							
Berrara Creek	E-338	3/12/2018	Summer	24.52	102.4	7.31	7.47	27.06		1.8							
Berrara Creek	E-338	3/12/2018	Summer								1	3	1	0.253		0.01	
Berrara Creek	E-338	11/04/2019	Autumn	18.7	122.5	9.25	8.17	35.52	53780	7.3							
Berrara Creek	E-338	11/04/2019	Autumn								1	3	1	0.235		0.013	
Berrara Creek	E-338	14/11/2019	Spring								1	2	1	0.241		0.0025	
Berrara Creek	E-338	15/04/2020	Autumn								11	27	1	0.624		0.0025	
Berrara Creek	E-338	23/11/2020	Spring	21.84	103.6		8.24	31.52		59.3	11	1	1	0.12		0.0025	
Berrara Creek	E-338	15/04/2021	Autumn								7	3	1	0.126		0.0025	
Berrara Creek	E-711	9/02/2010	Summer	24.8	104.1	7.13	7.59	33.53	51090	1.2		7	0				32000
Berrara Creek	E-711	22/06/2010	Winter	13.83	94.2	7.96		33	50380	25.9	0	2					23000

				Field							Biological		Algae indicator	Nutrients			Other
				Temperature	Dissolved Oxygen (% Saturation)	Dissolved Oxygen	pH	Salinity	Electrical Conductivity	Turbidity	Faecal Coliforms	Enterococci	Chlorophyll a	Nitrogen	Total Phosphorus	Total Phosphorus as P (Organic Phosphate as P)	TDS
		EQL		0.1	0.1	0.1	0.1		100	0.1	1	1	0.5	0.025	0.005	0.005	
Berrara Creek	E-711	17/01/2011	Summer	26.71	84.9	5.97	7.83	22.9	36290	21.3		62					
Berrara Creek	E-711	29/03/2011	Autumn	24.97	89.4	6.6	7.85	20.31	32600	0.2		4					
Berrara Creek	E-711	1/11/2011	Spring	22.29	47.9	3.8	6.35	15.57	25600	3.9		9					16000
Berrara Creek	E-711	14/11/2011	Spring	29.05	97.4	6.88	7.9	15.03	24750	37.8	29	10					
Berrara Creek	E-711	17/01/2012	Summer	24.86	44.9	3.4	5.83	16.7	27200	5.9	0	0					
Berrara Creek	E-711	28/05/2012	Autumn	12.82			5.58	20.5	32800	2.6	0	2					
Berrara Creek	E-711	29/01/2013	Summer	26.71			8.12	23.76	37520	46	360	980					
Berrara Creek	E-711	21/01/2014	Summer	24.84	86.5	5.85	8.03	35.57	53850	78.1	12	11					
Berrara Creek	E-711	30/04/2014	Autumn	20.68	80.5	6	8.03	32.46	49600	8.7	9	3					
Berrara Creek	E-711	12/11/2014	Spring	23.67	84.1	5.9	8.13	32.53	49700	7.8							
Berrara Creek	E-711	12/11/2014	Spring								1	1					
Berrara Creek	E-711	18/05/2015	Autumn								1	2					
Berrara Creek	E-711	24/11/2015	Spring	21.77	88.1	6.3	8.33	34.96	53000								
Berrara Creek	E-711	24/11/2015	Spring								1	1					
Berrara Creek	E-711	5/04/2016	Autumn	25.72	70.8	4.7	8.31	35.06	53200								
Berrara Creek	E-711	6/04/2016	Autumn	25.72	70.8	4.7	8.31	35.06	53200								
Berrara Creek	E-711	6/04/2016	Autumn								2	1					
Berrara Creek	E-711	21/11/2016	Spring	24.95	95.8	6.61	6.23	31.88		4.4							
Berrara Creek	E-711	21/11/2016	Spring								1	2					
Berrara Creek	E-711	4/05/2017	Autumn								20	17					
Berrara Creek	E-711	21/11/2017	Spring	24.6	42.9	2.98	8.17	31.94	48930	31							
Berrara Creek	E-711	21/11/2017	Spring								1	1					
Berrara Creek	E-711	17/09/2018	Spring								1	1					
Berrara Creek	E-711	19/09/2018	Spring	17.04	94.1	7.38	7.65	34.57	52500	2.3							
Berrara Creek	E-711	19/09/2018	Spring								1	1					
Berrara Creek	E-711	3/12/2018	Summer	24.14	71.8	4.94	7.16	34.53	52450	7.2							
Berrara Creek	E-711	3/12/2018	Summer								2	1					
Berrara Creek	E-711	11/04/2019	Autumn	19.73	109.6	8.13	7.87	35.38	53600	38							
Berrara Creek	E-711	11/04/2019	Autumn								1	1					
Berrara Creek	E-711	14/11/2019	Spring								1	1					
Berrara Creek	E-711	15/04/2020	Autumn								8	8					
Berrara Creek	E-711	23/11/2020	Spring	19.4	98.2		8.21	34.79		62.2	4	3					
Berrara Creek	E-711	15/04/2021	Autumn								1	1					
WQ Triggers												1052					

DoE (2000) ANZECC 2000 SE Aust Triggers - Estuaries

CoA (2018) ANZG (2018) DGVs -Protection of Aquatic Ecosystems Toxicants

NHRMC (2008) Primary contact recreational

Data Review Notes

Data range was restricted to 2010-current.

Only parameters with a min sample size of 10 were selected.

Data that were clearly erroneous due to instrument error or data entry were removed

Where errorenous results were seen in field data, the rest of that sampling period was reviewed to identify other errors as a result of incorrect calibration.

For micro values -1 were assumed to be <EQL and converted to EQL of 1, these are shown in orange.

Microbiology values <EQL were replaced with EQL, these are shown in orange.

For turbidity negative values were assumed as 0. This is common with water quality meters and can be calibrated within the sampling period by setting the lowest negative result as 0 and adding the difference to the rest of dataset.

Chemistry values that were reported as <EQL were converted by * 0.5, which is the recommended approach by ANZG.

It is likely that there has been some inconsistency in reporting <EQL with some values converted as negative or zero. Negative or zero values were converted to the next lowest EQL for purposes of calculating statistics.

For chemistry and field data, values over 4 standard deviations from the median were review and removed from dataset if obviously errors due to being outside the possible range for that parameter. Most of these were likely related to a calibration issue with field instrument, as consistent outliers were reported within the same month/sampling period. Other outliers were related to data entry (an extra 0 added).

turbidity values >100 were removed.

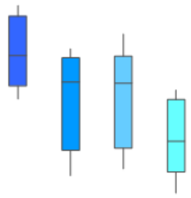
Dissolved oxygen % above 150 were removed.

EC below 100 at all sites during April 2018 were removed.

Appendix C
Water Quality Graphs 2010 - 2021

Boxplot graphs were prepared in Minitab 16.0 (2010) for key water quality parameters presented by site and season in Appendix D. Where practical, the relevant water quality guidelines (listed in Section 2.3.1) were included as reference lines on graphs (otherwise were noted in the figure caption).

In the boxplots, the following information is shown:



End of upper whisker = maximum value excluding outliers
Upper end of box = 75th percentile value
Middle line = median value
Lower end of box = 25th percentile value
End of lower whisker = minimum value excluding outliers

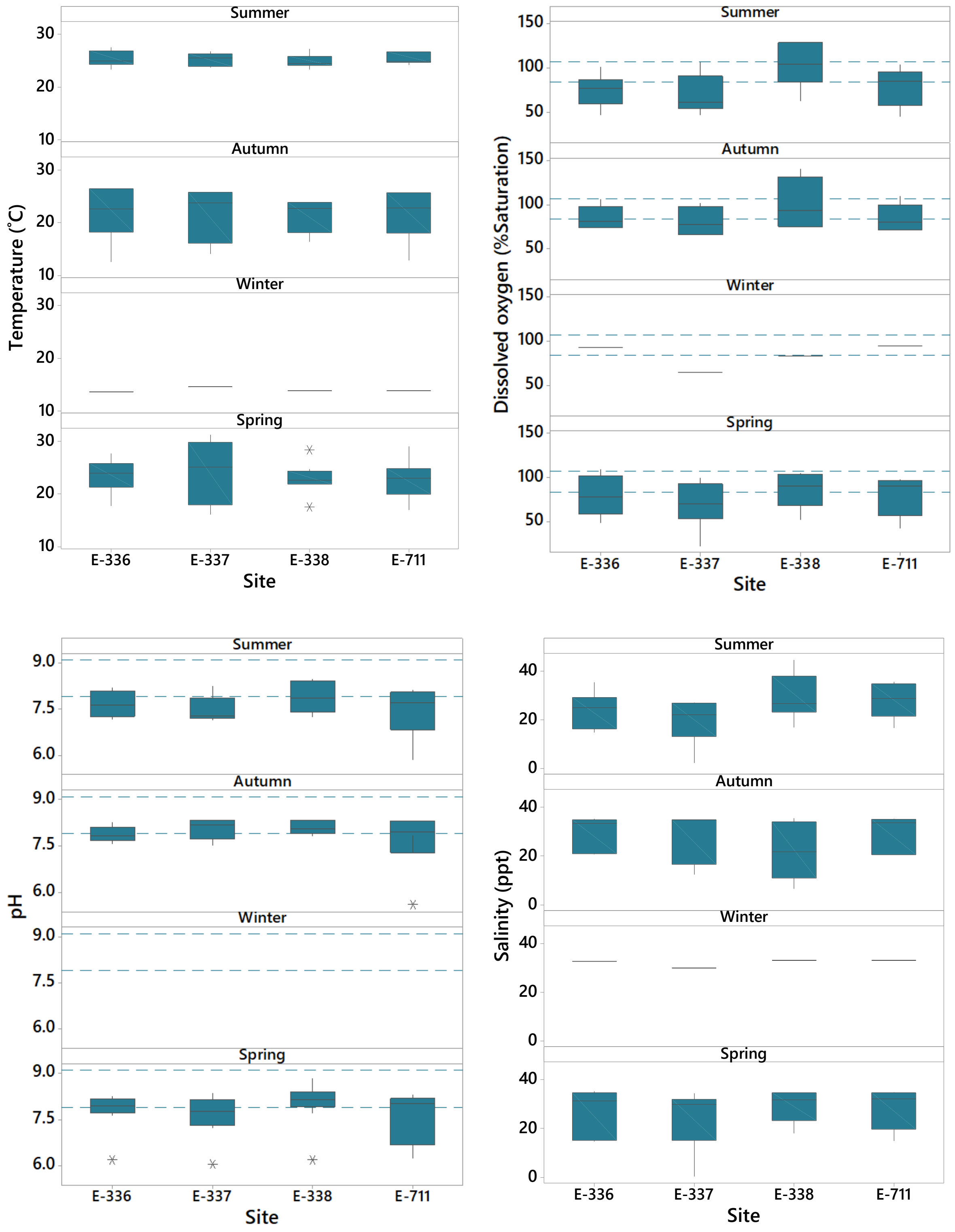


Figure 8-1 Temperature (°C), dissolved oxygen (mg/L), pH and salinity (ppt) by season in Berrara Creek from January 2010 - October 2021. The dotted lines show the DP&E MER guidelines for Lagoons.

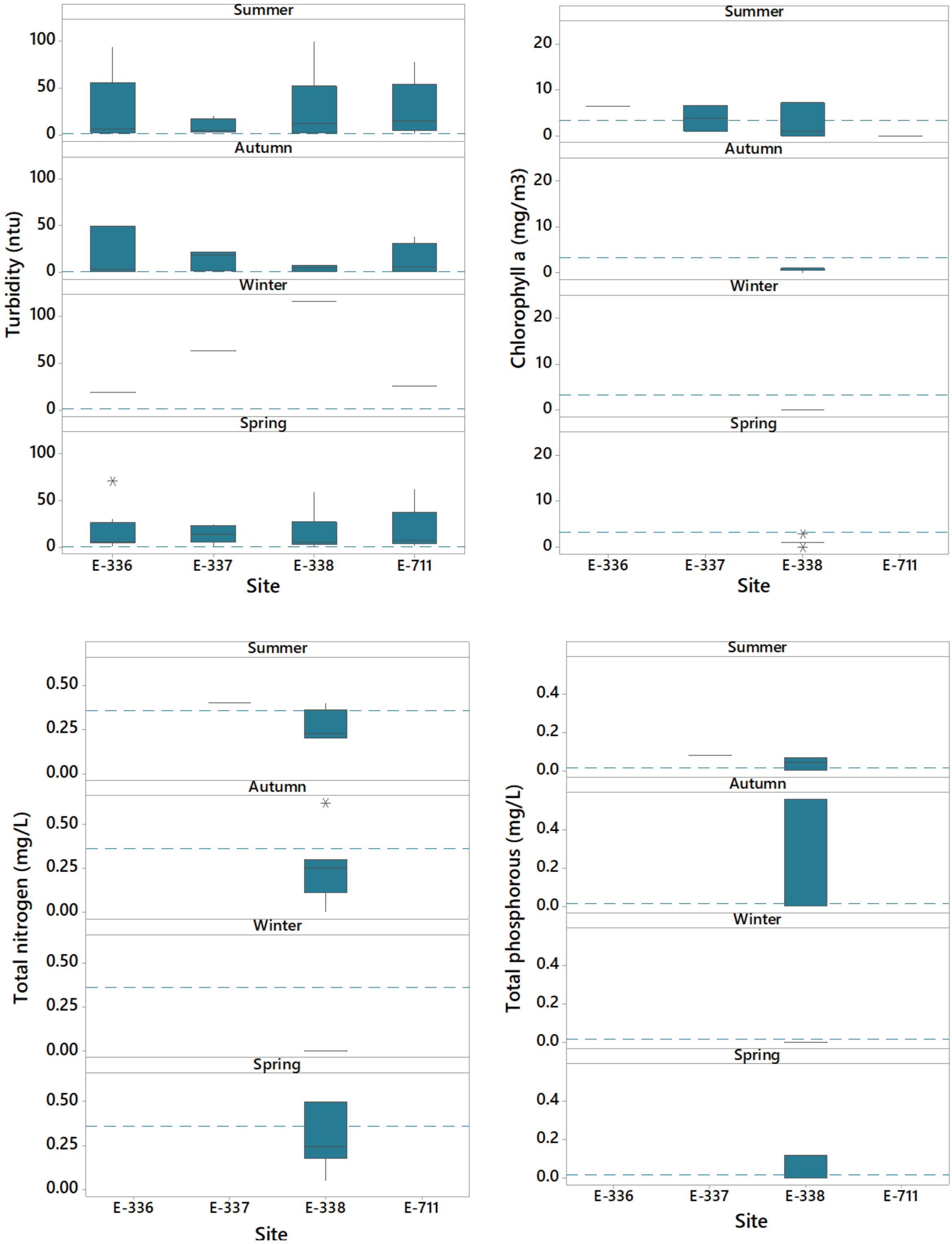


Figure 8-2 Turbidity (NTU), chlorophyll- a (mg/m^3), *total nitrogen as N (mg/L), total phosphorus as P (mg/L)* by *season in Berrara Creek from January 2010 - October 2021. The dotted line on the graphs show the DP&E MER guideline for Lagoons.*

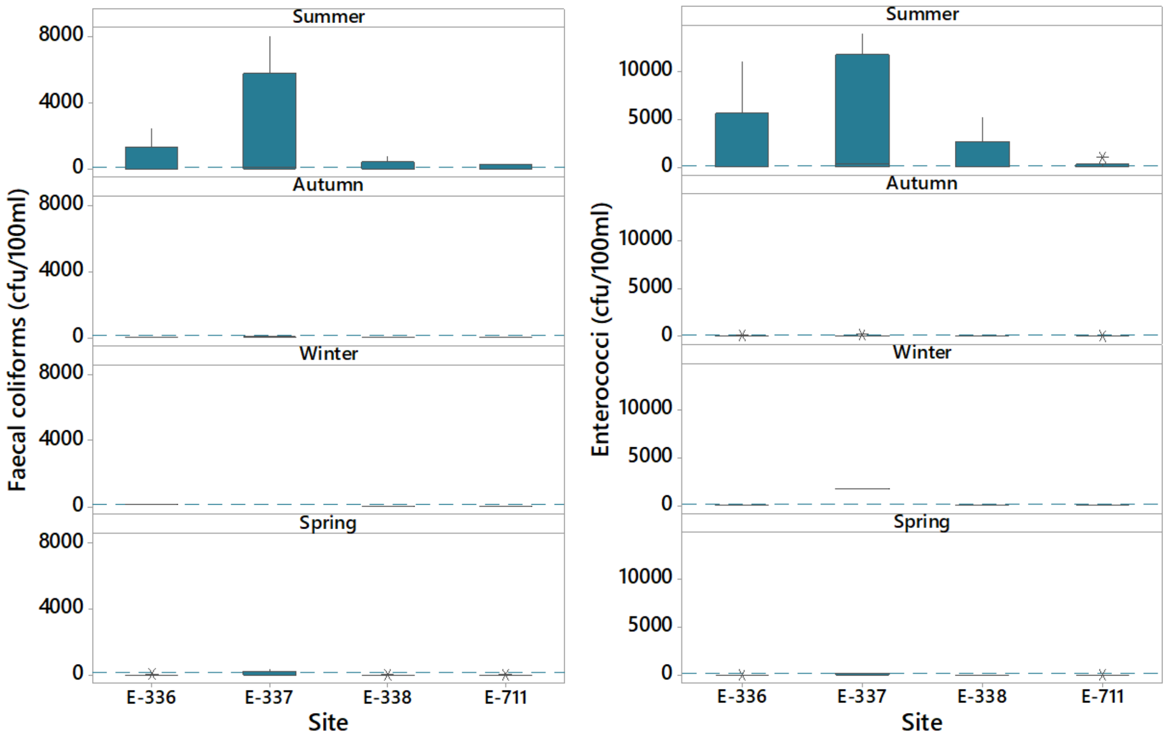


Figure 8-3 Faecal coliforms (cfu/100ml) and enterococci (cfu/100ml) by season in Berrara Creek from January 2010 - October 2021. The dotted line on the graphs shows the NHMRC (2008) Primary Recreational Guidelines, for comparison to median faecal coliform values and 95%ile enterococci values at recreational sites.

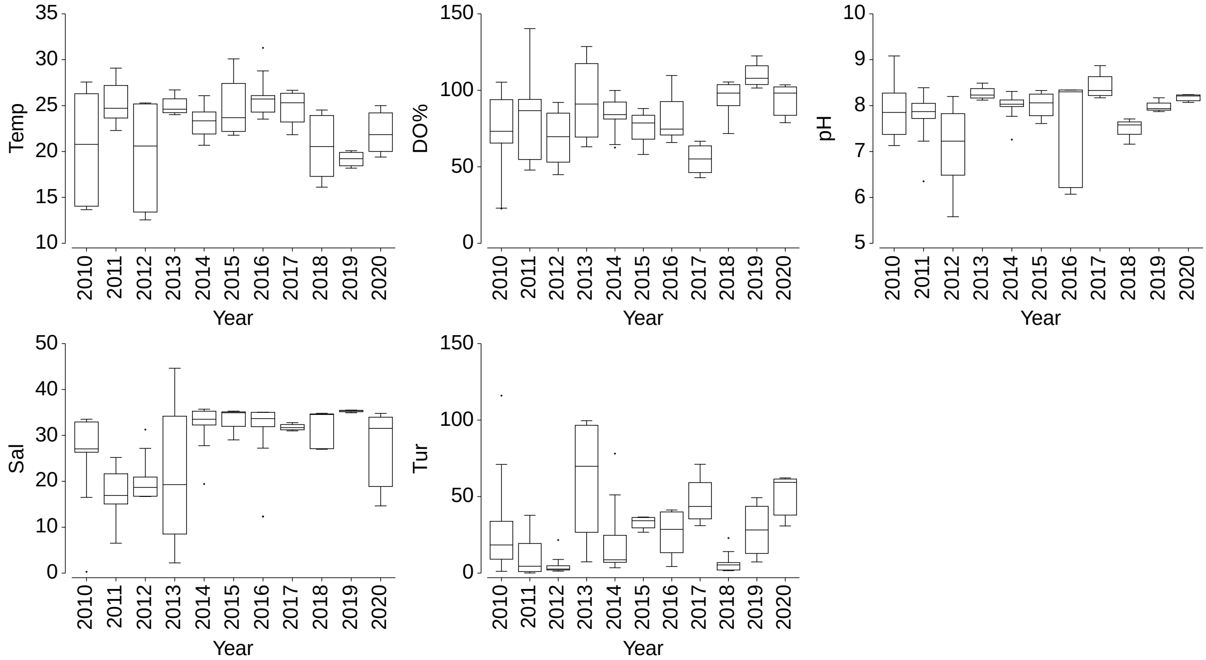


Figure 8-4 Summary of physicochemical parameters in Berrara Creek during available sampling years (all sampling sites pooled).

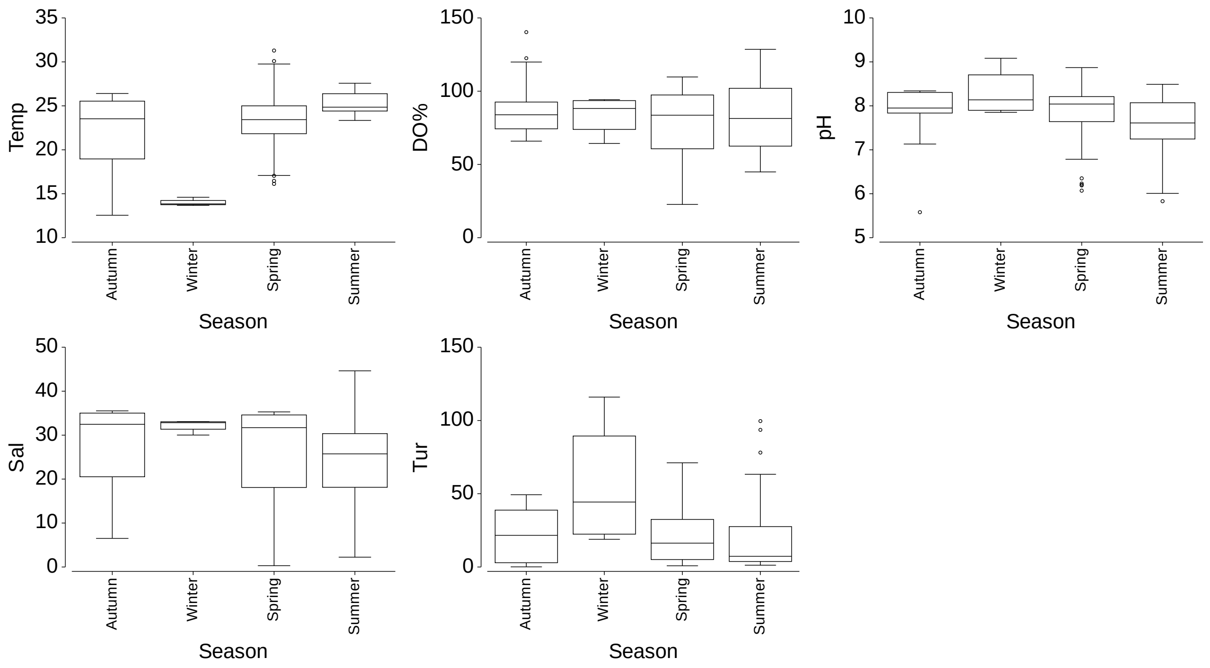


Figure 8-5 Summary of physicochemical parameters in Berrara Creek during available sampling seasons (all sampling sites pooled).

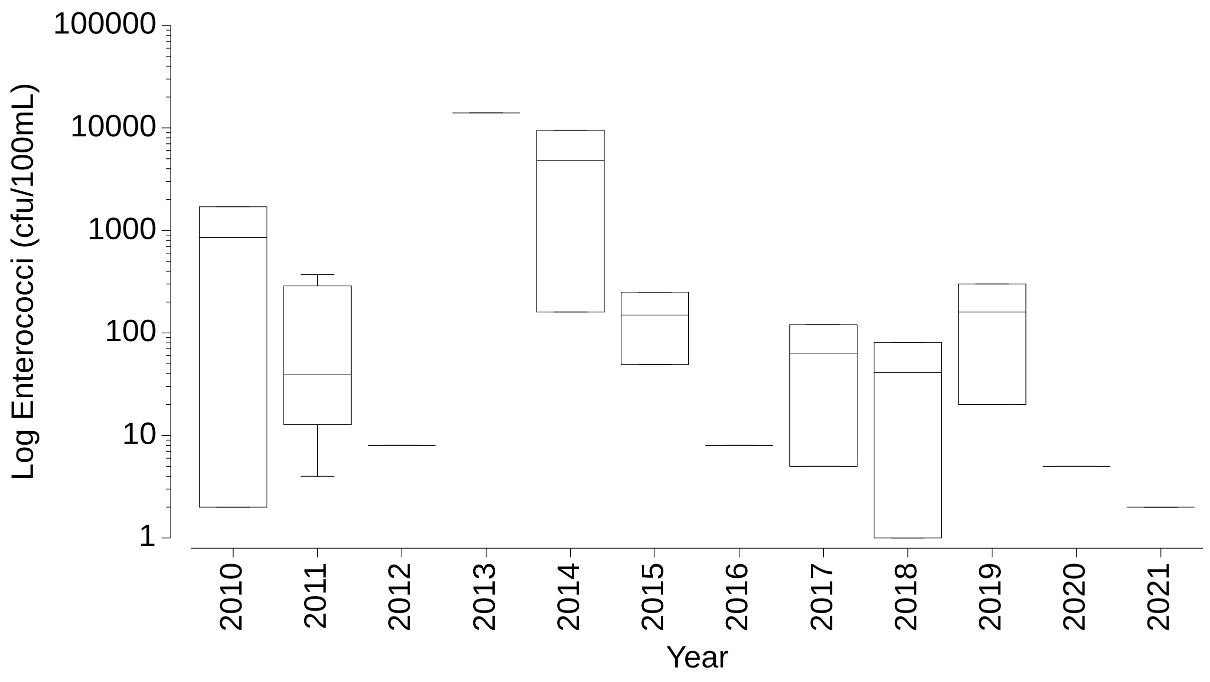


Figure 8-6 Summary of log enterococci at site E-337 during available sampling years.

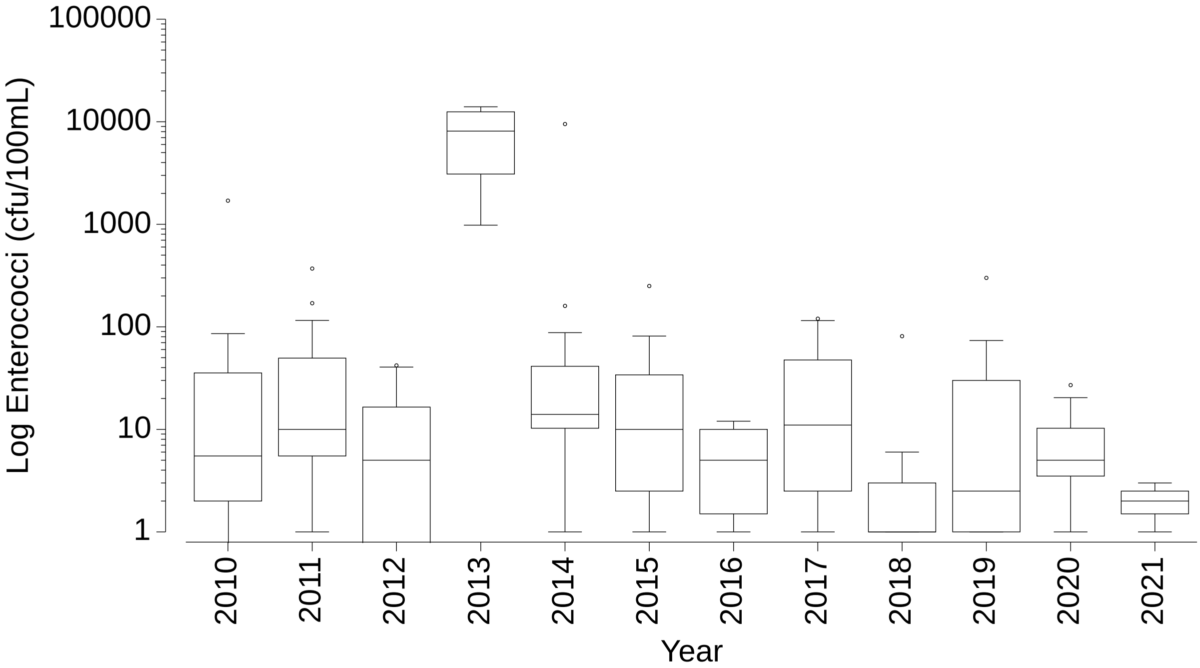


Figure 8-7 Summary of log enterococci during all available sampling years (all sites pooled).

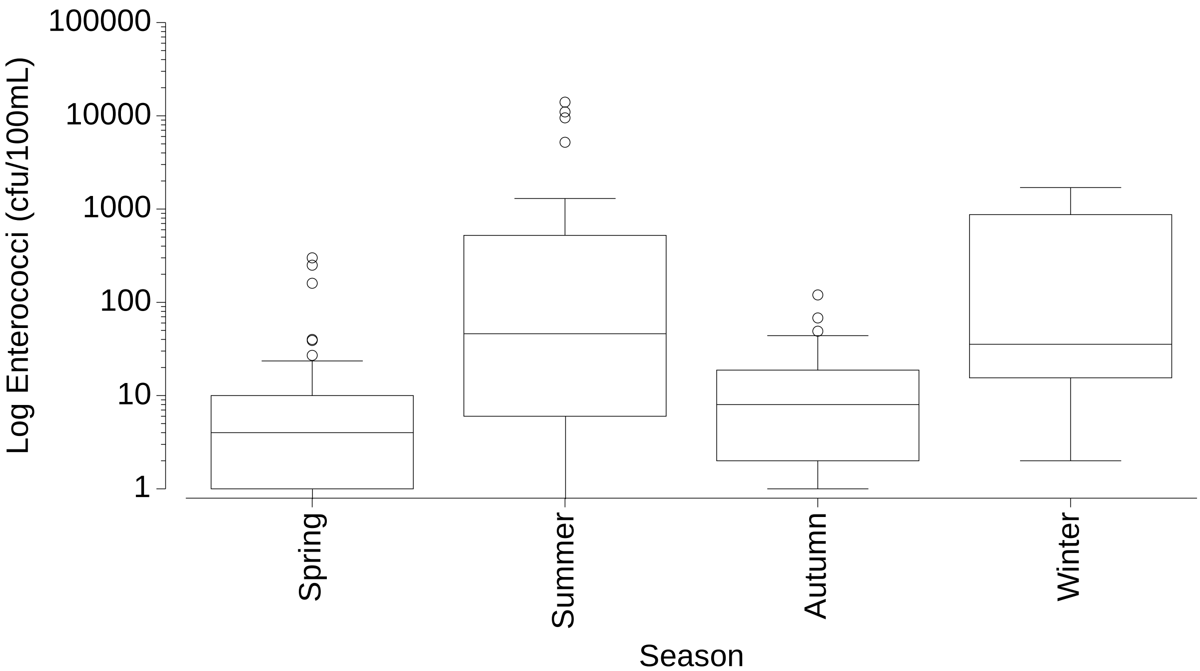


Figure 8-8 Summary of log enterococci in Berrara Creek during available sampling seasons (all sampling sites pooled).

Appendix D
Water Quality Analysis

Multivariate Analysis Methodology

Summary statistics for key water quality indicators were prepared in Minitab 16.0 and included the mean, median, minimum, maximum and standard deviation.

Multivariate analyses were undertaken in PRIMER7 with the PERMANOVA add on (Anderson et al. 2008; Clarke et al. 2014a) to determine differences in physicochemical water quality parameters between sites, areas, seasons or years. Due to the nature of multivariate analysis, there needed to be a matched dataset available for all parameters included in the analysis which restricted the data that could be included. The selected dataset used for analysis included sites within Berrara Creek during 2010 - 2021, where data was available for the following physiochemical parameters: temperature (°C), pH, salinity (PSU), DO (%) and turbidity (NTU).

For multivariate analysis, the data needs to be transformed to achieve similar distribution among the variables. The water quality dataset was transformed using log + 1 transformation which is typical for this type of environmental data. The transformed dataset was then used to make a resemblance matrix using the Euclidean similarity metric, which is robust to environmental data measured on different scales. A resemblance matrix is a matrix of scores which represents the pairwise similarity between each pairwise combination of data points. This matrix was used to generate multi-dimensional scaling (MDS) plots which were then overlaid with various factors of interest (e.g. area, site, season and year). Goodness of fit (stress) was assessed using Kruskal's stress formula and compared to maximum values (stress should be less than 0.2) as recommended by Sturrock and Rocha (2000).

Water Quality Analysis

The below graphs show the combined physicochemistry and chlorophyll-*a* data, where points that are closer together have more similar water quality and points further apart are more different. In each plot below, the points are in the same position but are shaded by the different factors of site, year and season. This allows a visualisation of whether there are differences between sites, years or seasons. Vectors were overlaid on the graphs of all physiochemical parameters and chlorophyll-*a*. The direction of the vector indicates sample points most influenced by that parameter and the length correlates to the strength of the relationship.

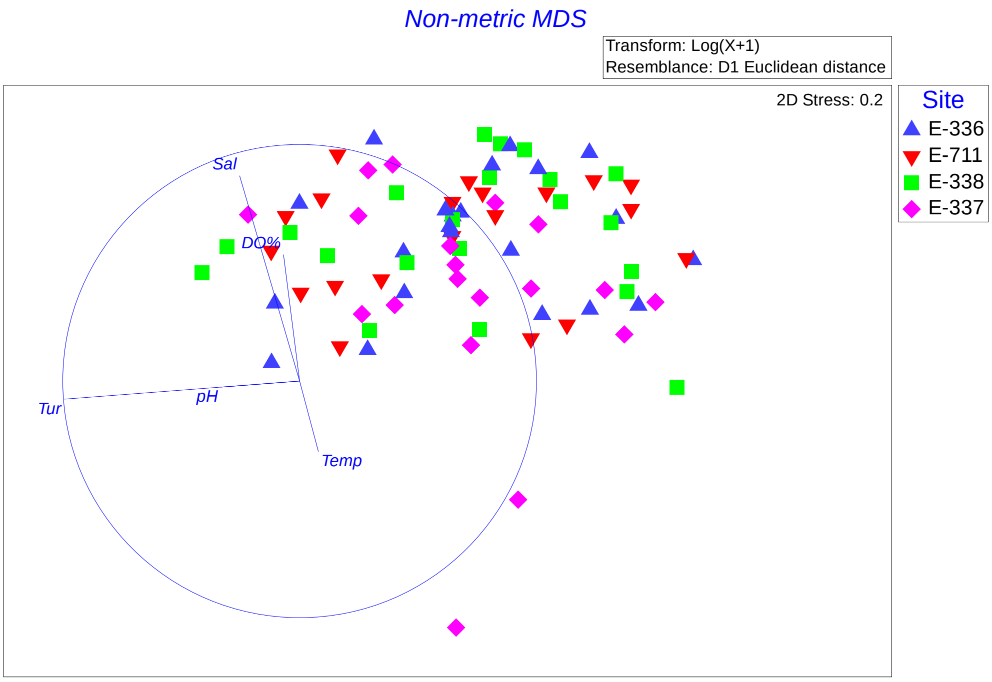


Figure 8-9 nMDS plot of water quality in Berrara Creek grouped by site.

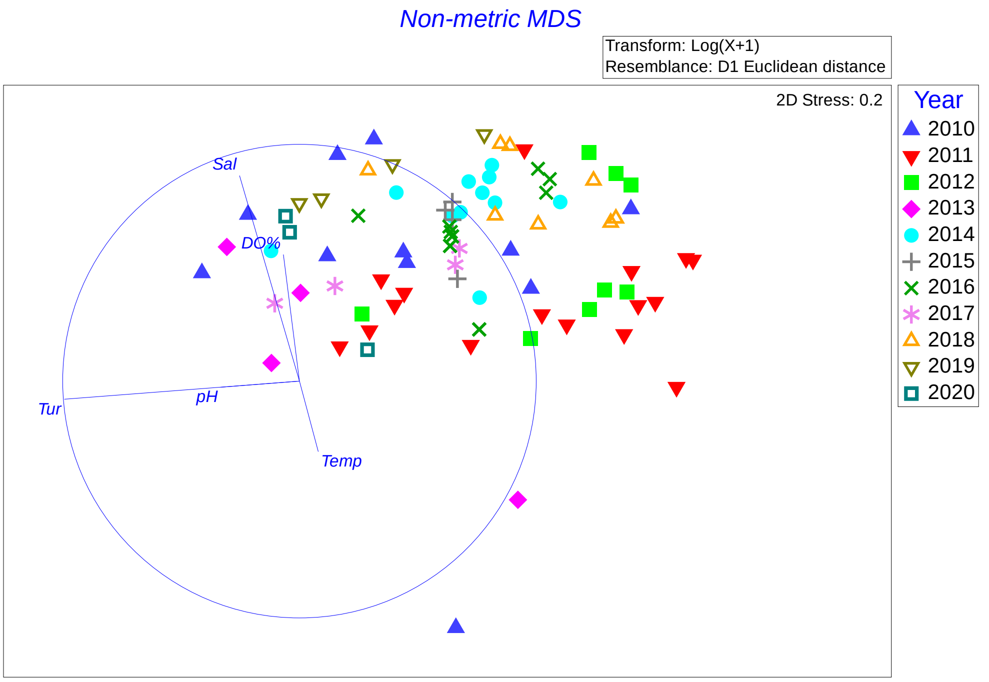


Figure 8-10 nMDS plot of water quality in Berrara Creek grouped by year.

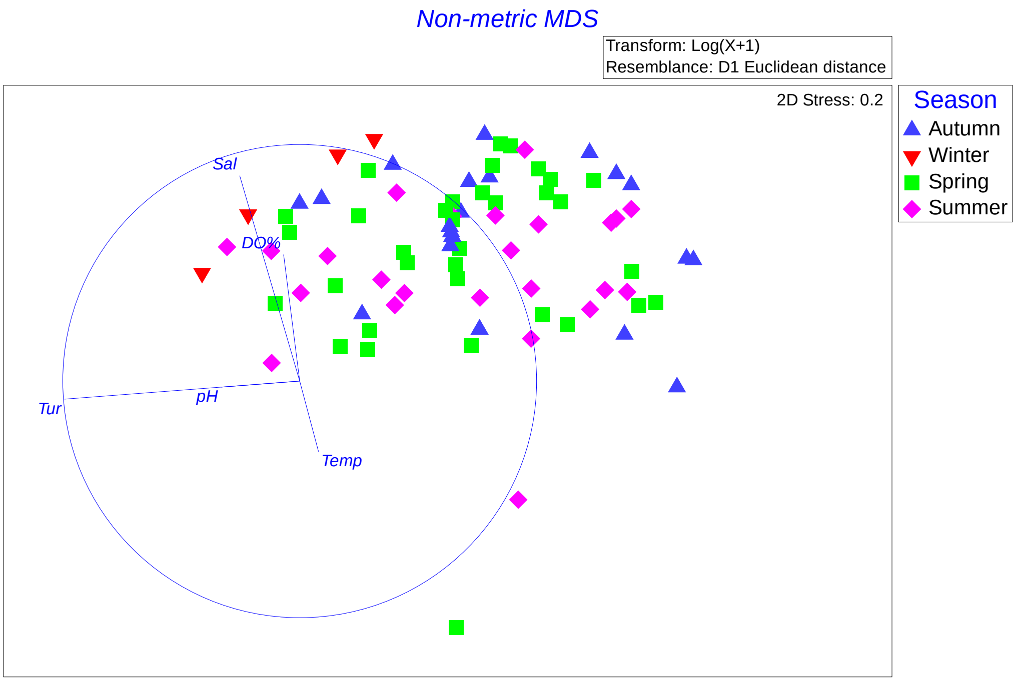


Figure 8-11 nMDS plot of water quality in Berrara Creek grouped by season.

Appendix E
DPIE Sanitary Inspection Template

Appendix A: Sanitary inspection report

Sanitary inspection report

+ Determination of Beach Suitability Grade

Version 11

Summary of findings

Site name: ________________________________ Site reference number: __________

Site visit date:______________ Council meeting date:______________

Sanitary Inspection Category (SIC): ______________ Determined on: ______________

Microbial Assessment Category (MAC): ___________ Calculated on: _______________

Matrix for determining the Beach Suitability Grade

Sanitary Inspection Category (SIC)	Microbial Assessment Category (MAC) (95th percentiles – enterococci cfu/100 mL)			
	A ≤40	**B 41–200**	**C 201–500**	**D >500**
Very Low	Very Good	Very Good	Follow up	Follow up
Low	Very Good	Good	Follow up	Follow up
Moderate	Good	Good	Poor	Poor
High	Good	Fair	Poor	Very Poor
Very High	Follow up	Fair	Poor	Very Poor

Beach Suitability Grade: _______________ for the year: __________

Entered into database on: _______________

This template can be used as a field sheet for the Beachwatch Sanitary Inspection Database or on its own as a sanitary inspection report. The template is available as a fillable form on the Beachwatch website.

For further guidance in determining the likelihood of pollution from each pollution source contact Beachwatch – beachwatch@environment.nsw.gov.au

Contents of the sanitary inspection report

1. Site information

Site name: ______________________________ Site reference number: __________

Type of site: ☐ Ocean ☐ Estuarine ☐ Freshwater

☐ Other ____________________________

Sandy beach? ☐ Yes ☐ No

Swimming dimensions: Length (m): ________ Width (m): _______ = Area (m^2): ________

Catchment area: __________ square kilometres

Catchment land use: Bushland: ________% Rural: ________% Urban: ________%

Contact details

Responsible authority: _________________________

Name: __________________________ Position: _________________________

Landline: ______________ Mobile: ______________ Fax: ________________

Email: ___________________________

Site location

Address: ____

Latitude: _________________________ Longitude: ________________________

Site description: ____

____

Diagram of site

1. Site information, cont.

Level of flushing:
- ☐ High (e.g. coastal beach)
- ☐ Medium (e.g. estuarine)
- ☐ Low (e.g. lagoon)

Elevated enterococci (>40 cfu/100mL):
- ☐ After light rain (5 mm in 24hrs)
- ☐ After moderate rain (10 mm in 24hrs)
- ☐ After heavy rain (20 mm in 24hrs)
- ☐ After very heavy rain (50 mm in 24hrs)

2A. Site use

Activities at site: ☐ Swimming ☐ Surfing ☐ Jet skiing ☐ Canoeing/kayaking

☐ Fishing ☐ Sailing ☐ Boating ☐ Diving

☐ Other ________________________________

Groups using site: ☐ Young children (<7yrs) ☐ Elderly (>60yrs)

☐ Adults & older children ☐ Tourists

Number of users: ________ to ________ people per day on weekends

________ to ________ people per weekday (non-holiday period)

________ to ________ people per weekday (holiday period)

Off-street parking? ☐ No ☐ Yes, number of bays: __________

Lifeguards: ☐ Unpatrolled ☐ Weekends ☐ Weekdays (non-holiday)

☐ Summer/School holidays

Do conditions deter people from entering?

☐ No ☐ Yes, details: ____

Any complaint of illness recorded?

☐ No ☐ Yes, details: ____

Consequence

☐ Minor

- Rarely used on weekdays
- Occasionally used on weekends or holidays
- Few people enter the water
- Location not popular with children or the elderly
- Location of minimal importance to the local economy

☐ Moderate

- Occasionally used on weekdays (e.g. <100 people per day for non-holiday period)
- Frequently used on weekends or holidays
- Most people enter the water
- Location very popular with children or the elderly
- Location of some importance to the local economy

☐ Major

- Frequently used on weekdays, weekends and holidays
- Most people enter the water
- Location very popular with children or the elderly
- Location of great importance to the local economy

2B. Pollution sources

Pollution source inventory

Pollution sources that could affect the water quality at the swimming site:

- ☐ Do **bathers** use the site?
- ☐ Are **toilet facilities** located within close proximity to the site?
- ☐ Are **wastewater treatment plants (including outfalls)** located within 2 km of the site?
- ☐ Do **designated sewage overflows** occur in the catchment (or within approximately 1 km radius of the site)?
- ☐ Do **sewer chokes or leakages** occur in the catchment (or within approximately 1 km radius of the site)?
- ☐ Do surrounding properties use **onsite sewage disposal systems**?
- ☐ Does **wastewater re-use** occur within 100 m radius of the site?
- ☐ Does **stormwater** discharge within 500 m of the site?
- ☐ Do **rivers** discharge within 1 km of the site?
- ☐ Do **lagoons** discharge within 500 m of the site?
- ☐ Are **boats** located in the vicinity of the site?
- ☐ Are **animals** (wildlife or domestic animals) present at the site?

Bather shedding

☐ Applicable ☐ Not applicable, details:______________________________________

Number of bathers at busy times: ________

Toilets available? ☐ No ☐ Yes, location: ________________________________

Bather density calculation

Use **area** as defined on the *Site details* sheet.

Use **number at busy times** as defined above.

Number at busy times:_________ *divided by* site area: ________ = _________ (people/m^2)

☐ Low (bather density <0.2)

☐ High (bather density ≥0.2)

Likelihood of pollution from bathers (select from the following matrix)

		Toilets available = YES		Toilets available = NO	
		Low bather density	**High bather density**	**Low bather density**	**High bather density**
Flushing	**Low**	Low	Moderate	Low	Moderate
	Medium	Very Low	Low	Low	Moderate
	High	Very Low	Low	Low	Moderate

Likelihood of pollution from bathers is: _______________

Is this likelihood appropriate? ☐ Yes ☐ **No, revised likelihood:** ________________

Comments/Justification: ____

____

____

Toilet facilities

☐ Applicable ☐ Not applicable, details:________________________________

Distance from toilets to site (m): ________

Total number of toilets: ________

Total number of showers: ________

Type of sewerage system: ☐ Sewered

☐ Onsite system, how often serviced?________________

Discharges/odours recorded? ☐ No, details: ________________________________

☐ Yes, details: ________________________________

____

Likelihood of pollution from toilet facilities (select from the following matrix)

		Distant proximity		Close proximity	
		Low use/flow	**High use/flow**	**Low use/flow**	**High use/flow**
Facility condition	**Poor**	Low	Moderate	Moderate	High
	Good	Very Low	Low	Low	Moderate

Likelihood of pollution from toilet facilities is: ____________

Is this likelihood appropriate? ☐ Yes ☐ **No, revised likelihood:** ____________

Comments/Justification: ________________________________

____

____

Wastewater treatment plant (within 2 km)

☐ Applicable ☐ Not applicable, details:________________________________

Name of outfall: ______________________________

Distance from site (m):__________

a. Discharges from wastewater treatment plants

Outfall type: ☐ Direct ☐ Short ☐ Long (offshore)

Treatment level: ☐ None ☐ Preliminary ☐ Primary ☐ Secondary + disinfection

☐ Tertiary ☐ Tertiary + disinfection ☐ Lagoon

Likelihood of pollution for discharges from wastewater treatment plants (select from the following matrix)

		Outfall type		
		Direct	**Short**	**Long (offshore)**
Treatment level	**None**	Very High	High	Low
	Preliminary	Very High	High	Low
	Primary	Very High	High	Low
	Secondary	High	High	Low
	Secondary + disinfection	Moderate	Moderate	Very Low
	Tertiary	Moderate	Moderate	Very Low
	Tertiary + disinfection	Low	Low	Very Low
	Lagoons	High	High	Low

b. Wastewater treatment plant bypasses

Average discharge volume per bypass event (mL):__________

Dilution of bypass effluent: ☐ High ☐ Low

Minimum treatment level of bypassed effluent:

☐ None ☐ Primary ☐ Secondary ☐ Tertiary/lagoon

Bypassed effluent disinfected: ☐ Never ☐ Sometimes ☐ Always

Bypass discharge location: ☐ Direct ☐ Short ☐ Long (offshore)

Wastewater treatment plant (within 2 km), cont.

Likelihood of pollution for wastewater treatment plant bypasses (select from the following matrix)

		Wastewater treatment plant bypass frequency (assuming effluent is not disinfected)				
		May occur in exceptional circumstances (1 in 10 years)	**Unlikely to occur but could occur at least once in a 5-year period**	**Might occur at least once or twice per bathing season**	**Will probably occur at least 3–4 times per bathing season**	**Will occur on a regular basis (once a week)**
Dilution (from discharge location)	**High**	Very Low	Very Low	Low	Moderate	High
	Low	Very Low	Low	Moderate	High	Very High

If there is no history of bypasses the likelihood of contamination for wastewater treatment plants is determined using the likelihood of pollution from wastewater treatment plant discharge matrix (a); however, if there is a history of treatment bypasses at the wastewater treatment plant the likelihood is determined by using likelihood of pollution for wastewater treatment plant bypasses matrix (b).

Likelihood of pollution from the wastewater treatment plant is:________________

Is this likelihood appropriate? ☐ Yes ☐ **No, revised likelihood:** ________________

Comments/Justification: ____

____

____

Designated sewage overflows

☐ Applicable ☐ Not applicable, details:____________________________________

For each overflow in the catchment (or 1 km radius), list:

Name	Address	Frequency/10yrs	Volume
______________	________________________________	______________	_______
______________	________________________________	______________	_______
______________	________________________________	______________	_______
______________	________________________________	______________	_______
______________	________________________________	______________	_______
______________	________________________________	______________	_______
______________	________________________________	______________	_______

Dilution: ☐ High ☐ Low

Likelihood of pollution from designated sewage overflows (select from the following matrix)

		Frequency				
		May occur in exceptional circumstances (1 in 10 years)	**Unlikely to occur but could occur at least once in a 5-year period**	**Might occur at least once or twice per bathing season**	**Will probably occur at least 3–4 times per bathing season**	**Will occur on a regular basis (once a week)**
Dilution	**High**	Very Low	Very Low	Low	Moderate	High
	Low	Very Low	Low	Moderate	High	Very High

Likelihood of pollution from designated sewage overflows is:_________________

Is this likelihood appropriate? ☐ Yes ☐ **No, revised likelihood:** _________________

Comments/Justification: ____

____

____

Sewer chokes and leakages

☐ Applicable ☐ Not applicable, details:________________________________

For each overflow in the catchment (or 1 km radius), list:

Date	**Address**
____________________	____
____________________	____
____________________	____
____________________	____
____________________	____
____________________	____
____________________	____

Dilution: ☐ High ☐ Low

Likelihood of pollution from sewer chokes and leakages (select from the following matrix)

		Frequency				
		May occur in exceptional circumstances (1 in 10 years)	**Unlikely to occur but could occur at least once in a 5-year period**	**Might occur at least once or twice per bathing season**	**Will probably occur at least 3–4 times per bathing season**	**Will occur on a regular basis (once a week)**
Dilution	**High**	Very Low	Very Low	Low	Moderate	High
	Low	Very Low	Low	Moderate	High	Very High

Likelihood of pollution from sewer chokes and leakages is: ________________

Is this likelihood appropriate? ☐ Yes ☐ **No, revised likelihood:** ________________

Comments/Justification: ____

____

____

Onsite sewage disposal systems

☐ Applicable ☐ Not applicable, details: ________________________________

Approximate number of systems in catchment: __________

Distance to site from nearest system (m): _________ (not including onsite toilet facilities identified under 'Toilets facilities')

Discharges/odours recorded? ☐ No, details: ________________________________

☐ Yes, details: ________________________________

____

Likelihood of pollution from onsite sewage disposal systems (select from the following matrix)

		Distant proximity		Close proximity	
		<50 systems	**≥50 systems**	**<50 systems**	**≥50 systems**
Condition	**Good – no complaints**	Very Low	Very Low	Low	Low
	Poor – history of odours and discharges	Low	Moderate	Moderate	High

Likelihood of pollution from onsite sewage disposal systems is: _______________

Is this likelihood appropriate? ☐ Yes ☐ **No, revised likelihood:** _______________

Comments/Justification: ________________________________

____

____

Wastewater re-use

☐ Applicable ☐ Not applicable, details:______________________________

Location of wastewater re-use area: ______________________________

Distance from site to re-use area: ____________

Wastewater treated prior to use? ☐ No ☐ Yes, details: ____________________

____

Likelihood of pollution from wastewater re-use (select from the following matrix)

		Distant proximity		Close proximity	
		Low volume	**High volume**	**Low volume**	**High volume**
Treatment level	**High – disinfected**	Very Low	Very Low	Low	Low
	Low – not disinfected	Low	Moderate	Moderate	High

Likelihood of pollution from wastewater re-use is: ____________

Is this likelihood appropriate? ☐ Yes ☐ **No, revised likelihood:** ____________

Comments/Justification: ______________________________

____

____

Stormwater

☐ Applicable ☐ Not applicable, details:______________________________________

Total number of drains at swimming site: __________

Pick the **two drains** that have the most influence on your sampling site (or if there is only one drain, enter its details).

Drain 1

Location: ______________________________ Authority: ______________________________

______________________________ ______________________________

Distance from site (m):___________________

Type of drain: ☐ Box culvert ☐ Creek ☐ Pipe

Discharge area: ☐ Dune ☐ Beach ☐ Offshore ☐ Direct <50m ☐ Direct ≥50m

Drain 2

Location: ______________________________ Authority: ______________________________

______________________________ ______________________________

Distance from site (m):___________________

Type of drain: ☐ Box culvert ☐ Creek ☐ Pipe

Discharge area: ☐ Dune ☐ Beach ☐ Offshore ☐ Direct <50m ☐ Direct ≥50m

Primary land use: ☐ High density urban ☐ Low density urban ☐ Rural – grazing

☐ Rural – cropping ☐ Bushland/reserve

Likelihood of pollution from stormwater (select from the following matrix – choose the highest likelihood if you have two different drains)

		Discharge area		
		Dune	**Beach, offshore or direct ≥50 m**	**Direct <50 m**
Land use	**High density urban**	Low	Moderate	High
	Low density urban	Very Low	Low	Moderate
	Rural – grazing	Very Low	Low	Moderate
	Rural – cropping	Very Low	Low	Low
	Bushland/reserve	Very Low	Low	Low

Stormwater, cont.

Likelihood of pollution from stormwater drains is: ________________

Is this likelihood appropriate? ☐ Yes ☐ **No, revised likelihood:** ________________

Comments/Justification: ____

____

____

River discharge

☐ Applicable ☐ Not applicable, details:________________________________

Name of river: ______________________________

Distance from discharge point to site (m): _________

Pollution sources in river discharge: ☐ Urban stormwater ☐ Leachate from onsite wastewater systems

☐ Agricultural runoff ☐ Intensive livestock production

☐ Other, details: _________________________

____

Likelihood of pollution from river discharge (select from the following matrix)

		Distant proximity		Close proximity	
		Low discharge volume	**High discharge volume**	**Low discharge volume**	**High discharge volume**
River water quality	**Good**	Very Low	Very Low	Low	Low
	Poor	Low	Moderate	Moderate	High

Likelihood of pollution from river discharge is: _______________

Is this likelihood appropriate? ☐ Yes ☐ **No, revised likelihood:** _______________

Comments/Justification: ____

____

____

Lagoons

☐ Applicable ☐ Not applicable, details:________________________________

Name of lagoon:_____________________________

Distance from site (m):__________

Area of lagoon (sq. km):__________

Catchment area (sq. km): __________

Sources of pollution to lagoon: ☐ Urban stormwater ☐ Agricultural runoff

☐ Other, details:_____________________________

____

% time open to ocean (recent average): ________

Entrance managed or modified?

☐ No ☐ Yes, details:____

Likelihood of pollution from lagoons (select from the following matrix)

Likelihood of pollution from lagoons				
Very Low	**Low**	**Moderate**	**High**	**Very High**
May occur only in exceptional circumstances, e.g. 1 in 10 years	Unlikely to occur but could occur at least once within a 5-year period	Might occur at least once or twice per bathing season	Will probably occur at least 3–4 times per bathing season	Will occur on a regular basis, e.g. once a week

Likelihood of pollution from lagoons is: ______________

Is this likelihood appropriate? ☐ Yes ☐ **No, revised likelihood:**_______________

Comments/Justification: ____

____

____

Boats

☐ Applicable ☐ Not applicable, details:________________________________

What is located near the site?

☐ Marina ☐ Permanent moorings

☐ Harbour ☐ Temporary moorings

☐ Anchorage ☐ Jetty

☐ Boat ramp ☐ Ferry berth

Distance from site to nearest boat (m): ___________

Number of boats near site:____________

Pump-out facilities provided?

☐ No ☐ Yes, details:________________________________

Complaints of boat discharges?

☐ No ☐ Yes, details:________________________________

Onshore toilets provided?

☐ No ☐ Yes, details:________________________________

Likelihood of pollution from boats (select from the following matrix)

		Number of boats		
		<20 boats	**20–50 boats**	**50–100 boats**
Waste management	**Good (holding-tanks required)**	Very Low	Very Low	Low
	Poor (holding-tanks not required)	Low	Moderate	Moderate

Likelihood of pollution from boats is: ________________

Is this likelihood appropriate? ☐ Yes ☐ **No, revised likelihood:** ________________

Comments/Justification: ________________________________

____

____

Animals

☐ Applicable ☐ Not applicable, details: ______________________________

Aquatic birds? ☐ Yes ☐ No

Density: ☐ Low ☐ Medium ☐ High

Roosting structures present? ☐ Yes ☐ No

Native animals? ☐ Yes ☐ No

Density: ☐ Low ☐ Medium ☐ High

Domestic animal exercise area? ☐ Yes ☐ No

Type: ☐ Dogs ☐ Horses ☐ Other, details: ______________________

Dog waste bags available? ☐ Yes ☐ No

Animals directly access water? ☐ Yes ☐ No

Area regularly cleaned? ☐ Yes ☐ No

Likelihood of pollution from animals (select from the following matrix)

Likelihood of pollution from animals				
Very Low	**Low**	**Moderate**	**High**	**Very High**
May occur only in exceptional circumstances, e.g. 1 in 10 years	Unlikely to occur but could occur at least once within a 5-year period	Might occur at least once or twice per bathing season	Will probably occur at least 3–4 times per bathing season	Will occur on a regular basis, e.g. once a week

Likelihood of pollution from animals is: ______________

Is this likelihood appropriate? ☐ Yes ☐ **No, revised likelihood:** ______________

Comments/Justification: ____

____

____

2C. Management

Which management controls are in place to warn people of periods of increased risk?

☐ None ☐ Permanent onsite signage ☐ Temporary onsite signage

☐ Media releases ☐ Beach closures ☐ Website

☐ Other, details: ____

Provide details of advisories: ____

____

____

Do management controls effectively prevent people from entering the water during these periods?

☐ No ☐ Yes, details: ____

____

____

Is there a management response plan in place to deal with exceptional events such as sewage overflows and bypasses?

☐ No ☐ Yes, details: ____

____

____

3. Calculating the Sanitary Inspection Category

On the **form on the next page** complete the following steps:

STEP 1: Fill out the likelihood for each of the pollution sources in the top part of the form (leave blank if pollution source is not applicable).

STEP 2: By referring to the table below, fill out the numerical likelihood values for these pollution sources.

Likelihood	Numerical likelihood
Very Low	0.1
Low	0.2
Moderate	1
High	3
Very High	12

STEP 3: Sum the numerical likelihoods.

STEP 4: By referring to the table below, fill out the numerical likelihood for animal pollution source (if applicable) in the second part of the form and sum the total numerical likelihood.

Likelihood	Numerical likelihood
Very Low	0.1
Low	0.1
Moderate	0.2
High	1
Very High	1

STEP 5: Using the total numerical likelihood, identify the Sanitary Inspection Category using the table below.

Total numerical likelihood	Sanitary Inspection Category
0–0.19	Very Low
0.2–0.99	Low
1–2.99	Moderate
3–11.99	High
>12	Very High

Pollution source	Likelihood		Numerical likelihood
Bathers	____________________	....	= _______
Toilet facilities	____________________	....	= _______
Wastewater treatment plant	____________________	....	= _______
Designated sewage overflows	____________________	....	= _______
Sewer chokes and leakages	____________________	....	= _______
Onsite sewage disposal systems	____________________	....	= _______
Wastewater re-use	____________________	....	= _______
Stormwater	____________________	....	= _______
River discharge	____________________	....	= _______
Lagoons	____________________	....	= _______
Boats	____________________	....	= _______
	Sum of numerical likelihoods		= _______

Pollution source	Likelihood		Numerical likelihood
Animals	____________________	....	= _______
	Sum of numerical likelihoods from previous table		= _______
	Total numerical likelihood		= _______

The **Sanitary Inspection Category** for this site is: ________________________